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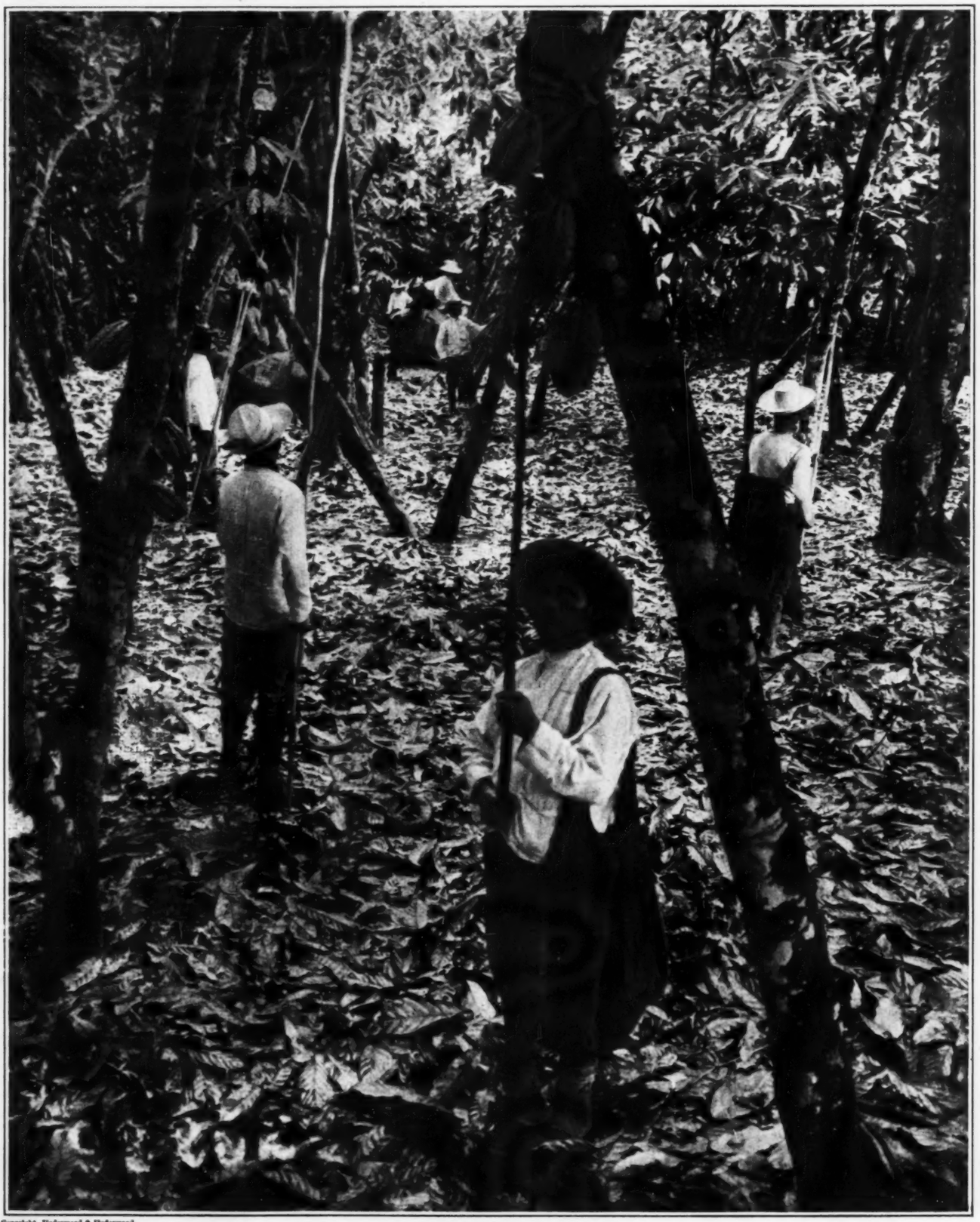

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Harvesting cocoa beans in Ecuador

CHOCOLATE AND COCOA [See page 232]

The Pathology of War Neuroses*

Disorders Not New in Kind, but Now of Frequent Occurrence

By Judson S. Bury, M.D., Lond., F.R.C.P. Lond., Major, R.A.M.C.(T.); Consulting Physician Manchester Royal Infirmary

It occurred to me that many of the so-called functional neuroses and also the reflex nervous disorders caused by injury have been observed by all of us, and that therefore, it might be of interest to review our knowledge regarding at least some of them. These disorders, which have been very prevalent during the present war, were previously well known to us in civil practice; the difference is one of frequency rather than of kind.

The symptoms of the neuroses are: mental confusion, stupor, headache, irritability, loss of memory, insomnia, nightmares, hallucinations, obsessions, disorders of the special senses, disorders of speech, disorders of motor functions (such as tremors, convulsions, contractures, and paralysis), and disorders of sensation.

"FUNCTIONAL" AND "ORGANIC" NERVOUS DISORDERS

At the outset let me say a word as to the difficulty of giving any precise definition of the terms "functional" and "organic."[1] These are commonly used in a pathological sense, being understood to imply the presence or the absence of some definite visible changes in nerve-tissue. But visibility is a relative term, it depends on our eyesight and the powers of our microscopes, and to some extent on staining reagents. Our methods of investigating nerve tissue are not infallible, and we must admit the possibility that even an emotion such as fear may produce minute changes in some of the cortical neurons.

If on the grounds of convenience the terms "functional" and "organic" are retained, two points should be clearly recognized—(1) the term "functional" ought to mean not the absence of morbid changes but only the absence of detectable changes; and (2) it ought not to be taken for granted that a disorder which has no known structural changes will run a more favorable course than one in which such changes are apparent. The lesions underlying paralysis agitans, epilepsy, and dementia præcox are unknown to us, yet we can scarcely regard these diseases as curable. Death may result from a profound chemical disturbance of the atoms and molecules of nerve tissue which leaves no visible trace, and between such changes and those which are conspicuous there must be every gradation both in size and nature.

Such gradations are well illustrated by the results of a study of "war neuroses." These neuroses may be produced in at least three ways; (1) by the breathing of poisonous gases, especially carbon monoxide; (2) by concussion of the central nervous system the result of aerial compression caused by the explosion of a shell; and (3) by emotional disturbance. Frequenty the neurosis is the result of a combination of these agents.

POISONOUS GASES

First, with regard to carbon monoxide, Col. F. W. Mott[2] has pointed out that if a man is buried under sandbags in a heavily shelled trench or dug-out, or if for any other reason he is confined in a small space in which the gas produced by an explosion collects, he will be rendered unconscious if he is not already unconscious as a result of concussion. In two fatal cases Mott found miliary punctiform hemorrhages in the white matter of the brain, the result of inflammatory stasis and thrombosis of small arteries. If consciousness is regained the man appears dazed and stupid and may suffer for a long time from headache, loss of memory, mental confusion, disturbances of speech, and tremors.

CONCUSSION OF THE BRAIN OR COMMOTIO CEREBRI

Apart from injuries received from fragments of a shell or from impact of the body against the ground or other solid substance, mere proximity to an exploding shell may be sufficient to cause detectable changes in the central nervous system.

In some cases the changes are severe enough to cause instantaneous death, probably owing to sudden arrest of the vital centres in the medulla from the enormous aerial compression; the force generated by 17-inch shells has been estimated as equal to 10 tons to the square yard. In other cases the changes are less severe and the man survives, but is subject to various symptoms indicating disorder of the nervous system. In many cases of shell shock the cerebro-spinal fluid withdrawn by lumbar puncture shortly after the shell explosion has shown increased pressure and has been found to contain evidence of the presence of blood, indicating that hemorrhage had occurred.

Recently Mott[3] has published a report of the examination of the brains in two cases of death from commotio cerebri without visible external injury and without the punctuate hemorrhages indicative of gas poisoning. His description serves to explain sudden death in shell shock as well as the clinical symptoms which persist for some time in non-fatal cases.

One of his cases was that of a captain who for six months prior to his fatal attack had suffered from much nervousness, which, however, he had kept under control. Later he was in an area which was subjected to an intense bombardment during which no gas shells were used; this lasted about four hours. On the following day six shells came over. He was not buried or gassed. One shell burst about two feet behind him. His symtoms were coarse tremors of the limbs, inability to walk or to do anything, together with crying and other hysterical manifestations. On the evening of the same day he was admitted to the field ambulance in a state of acute mania. He was quieted with morphine and chloroform and slept all night. The next morning he woke up apparently well and suddenly died.

The brain was extremely congested and there were a number of minute punctiform hemorrhages at the terminations of the smallest vessels on the surface of the brain, but there were no intracerebral hemorrhages. The cerebro-spinal fluid was blood-tinged. On microscopical examination minute scattered subpial hemorrhages were found almost everywhere. In the white matter of the corpus callosum, the internal capsule, the pons, and medulla there were congested vessels and hemorrhage into their sheaths with occasionally extravasations of blood corpuscles into the adjacent tissue. The cells of the central nervous system showed early chromatolytic changes.

From a study of these changes Mott assumes that the cells of this man were in a state of commencing nerve exhaustion; some nuclei of the cells were more markedly affected than others—for example, the cells of the vago-accessorius nucleus. Mott correlates the maniacal excitement during life with the marked venous congestion of the cortex and the subpial hemorrhages; the sudden death with the changes in the vago-accessorius nucleus, and the congested state of the medulla with hemorrhage into the sheath of a vessel in the median raphe of the medulla. He thinks that the cerebra anemia which was present and the chromatoyltic changes in the nerve cells may explain many of the symptoms of sufferers with true shell shock—namely, headache, giddiness, insomnia, stupor, mental confusion, and terrifying dreams—symptoms which are so common in recent cases.

The group of symptoms is similar to that which we have all observed in civil practice from concussion of the brain as a result of blows or falls on the head. In both cases there is a contused condition of the cerebral cortex. In many respects the symptoms resemble those of severe non-traumatic neurasthenia.[4] But I think that certain differences may be observed. Instead of an uncontrollable tendency to discuss their symptoms in detail, sufferers from a bruised brain are dull and apathetic and show a tendency to drowsiness and stupor rather than to insomnia. The neurasthenic is able to commence work and to do it accurately for a time, but he soon tires, he lacks concentration, and exhibits indecision in all his actions. But the patient with a bruised brain is unfit to follow any employment; he is too apathetic, as a rule, to show signs of worry or anxiety, and when his cortical lesion is severe and extensive apathy may be associated with profound loss of memory and other signs of mental deterioration.

EMOTIONAL DISTURBANCE

Thirdly, as to the effects of emotional disturbance apart from those of concussion or of the inhalation of poisonous gases. It is difficult for those of us who live quietly at home to visualize fully the terrifying conditions under which our comrades live at the front. When we think of the physical and mental strain of life in the trenches, of the shocks to the nervous system from the detonation of high explosives, together with the terror caused by the horrible sights of death and multilation around, we are not surprised to find that the strongest nervous system may be exhausted or even shattered. How much greater and more frequent must be the effects of such terrifying surroundings on soldiers whose nervous systems, in consequence either of some previous illness or injury, or of an inborn neuropathic or psychopathic taint, offer less than normal resistance to emotional stress. As Hubert Norman[5] remarks: "The exciting factor is important, but still more important is the condition of the organism upon which it acts."

In this class of neuroses and psychoses the most careful examination of the patient, both soon after his breakdown and later at a base hospital, reveals no evidence of organic disease of the nervous system. It is, however, scarcely conceivable that great emotions should not produce some bodily change; recent experimental work indeed, shows that definite changes do occur.

EFFECT ON SYMPATHETIC NERVOUS SYSTEM

The surface manifestations of pain and of great emotions, such as fear and horror, are well known to us. For example, "the contraction of blood vessels with resulting pallor, the pouring out of 'cold sweat,' the arrest of saliva so that the tongue cleaves to the roof of the mouth, the dilation of the pupils, the rising of the hairs, the rapid beating of the heart, the hurried respiration, and the trembling and twitching of the muscles, especially those about the lips."

But, as shown by the researches of Walter Cannon[6] and others, states of intense feeling are attended by disturbances not only in the superficial structures but also in deep-lying organs. These disturbances are similar to those brought about by great muscular exertion, and depend on nervous impulses to the sympathetic nervous system. Some of these impulses passing along the splanchnic nerves to the suprarenal glands lead to a pouring out of adrenalin into the circulating blood, which powerfully reinforces the action of the sympathetic nerves.

The result is that the vessels to the abdominal viscera are constricted, the blood pressure is raised, and the blood is driven from the abdominal viscera to the heart, lungs, brain, and skeletal muscles. Another effect of adrenalin is to transform the glycogen in the liver into sugar, which circulating in the blood gives renewed strength to the muscles. Moreover, adrenalin brings about a rapid recovery of muscle after its irritability has been lowered by fatigue, and it tends to neutralize or destroy the toxic substances produced by muscular or nervous work. During strenuous muscular action, especially if associated with emotional excitement, the respirations become rapid and forced in order to draw in more oxygen and to get rid of the excess of carbon dioxide. This ventilation of the lungs is much aided by the action of adrenalin in relaxing the smooth muscles of the smaller bronchial tubes.

In these various ways, then, muscular action is rendered more efficient by the changes in the viscera brought about by emotion. The shifting of blood from the abdominal organs to the organs immediately essential to muscular exertion—namely, the lungs, heart, and central nervous system—the increased vigor of the heart, the quick abolition of the effects of muscular fatigue, the mobilizing of energy-giving sugar in the circulation, all help to render the organism more effective in the violent display of energy which fear or rage or pain may involve. Reservoirs of power are called forth which enable a man to perform feats of strength and endurance far beyond his normal capacity.

If the various energizing substances—adrenalin, sugar, and probably also thyroid secretion—the products either of fear or of the fury and excitement of battle, are not worked off by muscular action it is conceivable that their presence in excess in the blood may lead to patholgical effects; in other words, the cessation of physical exertion while strong emotions are dominant may be followed by a disordered action of both mind and body, which later, as when the soldier reaches a base hospital, is expressed by tremors, by tachycardia, by starting at the slightest noise, and by terrifying dreams of the horrors he has witnessed.

In severe cases the continued over-action of the suprarenal, and probably also of the thyroid glands, may produce a clinical picture similar to that of Graves' disease. Sometimes sugar is present in the urine. There is, indeed, clinical evidence that occasionally glycosuria and even diabetes may be originated by emotional disturbance. Schultze believes that the amount of glycosuria depends on the degree of mental depression, and that the greatest excretion of sugar occurs in the fear-psychoses.

PSYCHIC EFFECT

Now, the effects of emotional shock can scarcely be limited to the changes which, as we have seen, appear to be due to stimulation of the sympathetic nervous system. Surely, they must also produce some change in the neurons of the central nervous system. The exact nature of such change is unknown to us, and is not likely to be revealed by a microscopical examination of dead

*An address to the officers at the Lord Derby War Hospital, at Warrington, England, from a report in *The Lancet*.

neuronic tissue. It is only by researches on the living neuron that we can expect to obtain any satisfactory knowledge.

Crile[7] has demonstrated by laboratory experiments that "in an animal driven strongly by emotion" there is a "mobilization of the energy-giving compound in the brain cells, evidenced by a primary increase of the Nissl substance and a later disappearance of this substance and the deterioration of the cells." He says that the cell-changes due to the emotions are "so similar, and in extreme conditions approach so closely to the changes produced by disease, that it is impossible to say where the normal ceases and the abnormal begins." We have also to consider the association and dissociation of neurons which may occur, and which may be due to attraction and retraction of their dendrons. How, then, can we divide cases clinically into functional and organic?

In a consideration of the various agents that may originate and maintain a neurosis one factor—namely, repression—must not be overlooked. Fear must affect every soldier at some time or other during his life at the front. With many men, especially those who are highly strung, the fear of being afraid is always before them—the fear that they may fail at the critical moment to do what is required of them. (An interesting case is related by Prof. G. Elliot Smith.[8]) The almost incessant efforts to repress such fear must have an injurious effect on the mental and bodily functions and tend to prepare the way for a nervous breakdown.

The result of repression of the emotions is often seen in men under treatment in home hospitals. The voluntary process of an attempt to remove painful memories and thoughts out of the field of attention, instead of being beneficial, may take an active part in accentuating the mental distress, in maintaining the neurosis, and also in the development of new symptoms. In some patients there is an attempt to banish from the mind feelings of shame due to their having broken down; in others grave apprehensions about fitness for further service, which are repressed owing to the idea that such thoughts are equivalent to cowardice, or might be so interpreted by others.

Rivers[9] points out that the advice usually given to such patients is that they should try to banish all thoughts of war from their minds, and they are instructed to try to think of other things such as beautiful scenery and other pleasant aspects of existence. Now, although there is much soundness in this policy, and although no one would advise the patient to concentrate his thoughts on painful memories or brood upon feelings of regret and shame, much harm may be done by an attempt to banish them wholly from the mind. If in place of thrusting aside such distressing thoughts the patient faces them boldly and talks openly with his doctor about them his general health is much more likely to improve, his power of sleeping to be increased, and his sleep to be less disturbed by terrifying dreams of warfare.

But for further discussion of this important subject and for records of suggestive cases I must refer you to Rivers' very interesting and valuable paper.

HYSTERIA

Hitherto we have been mainly dealing with what I may call the pathogenesis of war neuroses. Now we may ask regarding the symptoms which we observe. Can they all be adequately explained by such bodily changes as I have mentioned; or have we to introduce other factors, especially that subtle psychical condition which we call Hysteria? The subject of hysteria is very complex, and there are many views regarding the nature of this disorder. One of the most important is that of Babinski, who regards hysteria as essentially a matter of suggestion. He defines it as a pathological state manifested by symptoms which it is possible to reproduce exactly by suggestion in certain subjects, and which can be made to disappear by the influence of persuasion or counter-suggestion alone.

All the facts bearing on the development of hysteria have been admirably discussed by Babinski and Froment.[10] They review their own observations during peace and war, as well as the accounts given by trained observers who were present at times of great emotional stress, such as earthquakes, railway accidents, shipwrecks, and heavy bombardments at the front. They conclude:

"That emotion alone, however intense it may be, does not produce hysterical disorders, and although emotions may prepare the mind to submit to suggestion, they nevertheless exclude suggestion for the time being, and when they are intense they prevent the development of hysterical disorders or even cause them to disappear. When the human soul is shaken by a profound emotion there is no room left in it for hysteria."

One account which they quote is by Clunet, who was traveling on the transport *La Provence* at the time when she was torpedoed:

"Clunet saw no hysterical symptoms during the 17 minutes which elapsed before the boat sank, nor during the 18 hours he spent on a raft. There were manifestations of extreme emotion in the boat and of physical suffering on the raft, but it was not until they were picked up by a destroyer that some of the men showed paralysis, mutism, and other hysterical symptoms, all of which Clunet cured within a few hours by vigorous counter-suggestion, with such success that no relapse occurred during the eight following days whilst they remained under observation."

Similarly, real hysterical manifestations are rarely met with at the front. Emotional symptoms are common enough, men reaching the aid-posts weeping and tremulous, with rapid pulse and respiration. It is only at the base and in home hospitals that hysterical symptoms are common, the reason being that there has been time for suggestions to enter the mind during its recovery from a state of confusion. The particular symptoms that develop—whether paralysis, anaesthesia, mutism, or deafness—depend on the mental impressions received by the patient in consequence either of some morbid sensation of his own or of some circumstance attending the method of examination by his doctor.

The old conception of hysteria as held by Charcot and his contemporaries was very wide, and included a large number of disorders which are now known to have a different pathology. Babinski has done good service by trying to narrow this conception, and without attempting to discuss his theory of suggestion it will be useful to consider whether certain manifestations of these war neuroses which are still often regarded as hysterical may not be explained by physical rather than by psychical agency.

REFLEX NERVOUS DISORDERS

I will limit my remarks to certain contractors and paralyses which develop after injury and which in their character, distribution, and associations present a close resemblance to the condition known as arthritic muscular atrophy. The fact that inflammation of a joint is almost invariably attended by rapid wasting of the muscles that cover the joint was first described by John Hunter. He recognized also that the atrophy is not the result of default of movement, for he says when the other limb is examined it is seen that the muscles there have preserved their volume, although they have not been more moved than the muscles of the diseased limb. He also noted that the muscles were sometimes paralyzed, even when they were not atrophied.

Ollivier in 1869 was the first, I believe, to suggest the reflex nature of the phenomenon. Subsequently many theses and articles were published, including one by Charcot, who describes the condition with his usual lucidity and dramatic force. About 30 years ago I was much interested in this subject and in a published paper reviewed our knowledge concerning it.[11] Let me give a simple example:

"A man injures his knee; it becomes painful and swollen; in a short time the muscles of the affected limb become weak and wasted, but both weakness and wasting marked in the quadriceps extensor. A measurement taken a week after the injury may show a difference of an inch between the girths of the thighs. The knee-jerk is exaggerated, and sometimes also on the unaffected side.

"Other examples are: the wasting of the interossel and the muscles of the forearms in rheumatoid arthritis of the hands, of the beltoid in injuries of the shoulders, of the glutei in hip disease, and so on."

In explanation of these symptoms no better hypothesis than that of Charcot has yet been advanced—namely, that the nutrition of the motor cells in the spinal cord is damaged in a reflex manner, morbid influences being conveyed to them by the joint-nerves, and that their derangement or torpor determines the changes in the muscles. That the process is reflex was indeed shown by Raymond, who found that a previous division of the posterior spinal roots prevented the wasting of the muscles. In some cases the atrophy is persistent, and may spread to other muscles of the limb. I have seen cases which suggest that occasionally progressive muscular atrophy may be initiated in this way.

Now, curiously enough, these reflex nervous disorders, which may follow not only joint affections but also slight wounds to a limb or its injury by frostbite or in other ways, have been overlooked or discredited, and in many modern text-books on medicine there is little or no reference to them. The discredit into which the old views had fallen is largely due to the exaggerated development of the idea of hystero-traumatism—that is, to attribute to hysteria almost all the nervous disorders following traumatism and not due to a definite lesion of the nervous system. In their book Babinski and Froment have published important observations on these reflex neuroses and have given a full description of the atrophic paralysis and spasms which occur, and also of the other symptoms that may be associated with them—namely, increased excitability and slow contraction of muscles on mechanical stimulation, disturbances of sensation, of temperature, and of vaso-motor control as shown by coldness and cyanosis of the affected part, and, lastly, trophic changes in the bones and skin.

Several instances of these reflex disorders have come under my care during the present war. In Babinski and Froment's book will be found a number of completely new observations, as well as a discussion of the diagnosis of these disorders from other paralyses and contractures, whether they be of hysterical or of organic origin.

CONCLUSION

In conclusion, I would emphasize the importance of recognizing the gradual transitions that occur, both as regards symptoms and pathology, between emotional disorders and serious disease of the central nervous system. Think only of conclusive seizure. Can the most experienced neurologist who watches it closely always tell whether it is due to malingering, to hysteria, or to epilepsy?

I would also draw attention to the similarity in symptoms that may be sometimes observed in functional and organic diseases. Cases of concussion of the central nervous system from shell explosion have been described which presented the symptoms of disseminated sclerosis, of cerebellar disease, or of general paralysis of the insane. Major Eager of this hospital, who has had such a large experience of mental disease, has told me that he is much impressed with the striking resemblance between the symptoms of some cases of shell shock and those of general paralysis. This suggests that similar groups of cortical cells are deranged in the two diseases; in the one by a specific poison which ultimately will lead to their complete destruction, in the other by the results of concussion or of profound emotional disturbance the effects of which may be expected entirely to pass away.

Lastly, we must remember the frequency with which hysterical manifestations may be grafted on to a basis of organic disease, and therefore the importance of making a thorough examination of every case which appears to be hysterical, in order that no sign of structural change may escape our notice.

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Treatment of Straw for Preparation of Fodder

ACCORDING to Lehmann the digestibility of the organic matter of winter-sown cereal straw can be taken as 42 per cent, and the different processes of treatment aim at increasing this value. Lehmann's pressure method using a minimum of soda (2 per cent of the straw), increases the digestibility to 60-62 per cent, and the product can be fed without danger. By employing more soda (10 per cent of the weight of the straw) the digestibility can be increased to 74 per cent, but the product must be washed with water, thus entailing a loss of 30 per cent of the original straw. The increased value of these products balances this loss, but it is an open question whether the process justifies the increased expenditure on soda. Lehmann's process without pressure, but using more soda (10 per cent), also requires that the material be washed, and again there is a loss of organic matter. This method increases the digestibility to over 70 per cent, but requires a longer time than the pressure method. Similar results were obtained by Colsmann in experiments carried out at Dahlem, using closed boilers without pressure and with excess of soda. The treatment without pressure or shaking yields a material ("*Kraftstroh*") which is still of the nature of straw. By treatment under pressure a uniform mass is obtained which in the wet state can be fed satisfactorily; in the dry state, however, it is similar to cardboard and is not satisfactory to feed. If the wet "*Kraftstroh*" is mixed with molasses, potatoes, or with products rich in nitrogen and dried, a mixture is obtained which keeps well, can be transported, and is readily consumed. The treated straw has a digestibility exceeding that of meadow hay (60 per cent) and equal to that of clover (70 per cent).—*Note in J. Soc. Chem. Ind. on an article by B. Tollens in Z. angew. Chem.*

The Stokes Bomb-Throwing Gun—II*

And Its Development

By Sir Wilfred Stokes, K. B. E.

[Concluded from Scientific American Supplement, No. 2231, Page 213, October 5, 1918]

THE PROJECTILE

Having dealt so far with the details of the gun, I will now return to the projectile.

It will be remembered that my original idea was to have a projectile formed with a number of chambers holding explosive which should be arranged to give successive explosions in different positions. The first

Fig. 11. Original cast iron shell—dissembled

conception is shown in Figs. 11 and 12. It is formed in two parts secured by a central bolt and arranged with time fuse connections between the chambers. I very soon found this scheme impracticable as the first or second explosion opened the joint and the remaining chambers went off simultaneously.

I next tried a bundle of separate cast-iron chambers with external fuses. (See Fig. 13.) This also was a failure as the violence of the first explosion broke up and fired the rest. By this time I was officially told that the "bouncing" idea was not acceptable. For my own satisfaction, however, I made a final effort, which turned out fairly satisfactory. This device consisted of four concentric chambers holding black powder and formed by fitting cast iron cylinders one outside the other and so shaped that the ends were closed. (Fig. 14.) A short length of time fuse was attached to each chamber of such relative lengths that the explosions took place successively beginning with the outer chamber and finishing with the center one. This scheme had the desired effect of successive bouncing explosions but the construction was too complicated and heavy to encourage the attempt to obtain its adoption.

From this time onward I devoted my attention to the production of a shell having sufficient accuracy and a single bursting charge.

As the gun barrel was not rifled the projectile when fired very quickly began to turn over in its flight and the question arose as to whether or not some arrangement should be made to make it fly end-on. Various expedients were tried but nothing gave such uniform results as the shell shown in Fig. 15 which has a body formed more or less on stream lines with wings at the tail end. For various reasons however, this design was not adopted although latterly there seems to be a movement in the direction of using a cast iron shell with wings.

I next experimented with a simple cylindrical cast iron shell shown in Fig. 16 which held about 1 lb. of black powder and the fragmentation of which was

Fig. 13. Cast iron compound shell with six chambers

quite good. This design involves very little machining and is simple and cheap to make.

The final design adopted, however, is shown in Figs. 17 and 18 and consists of a piece of wrought steel tube forming the body, with screwed-in ends thus giving a very light construction capable of holding about three times as much high explosive as an 18-pounder service shell. The screwed-in ends have to

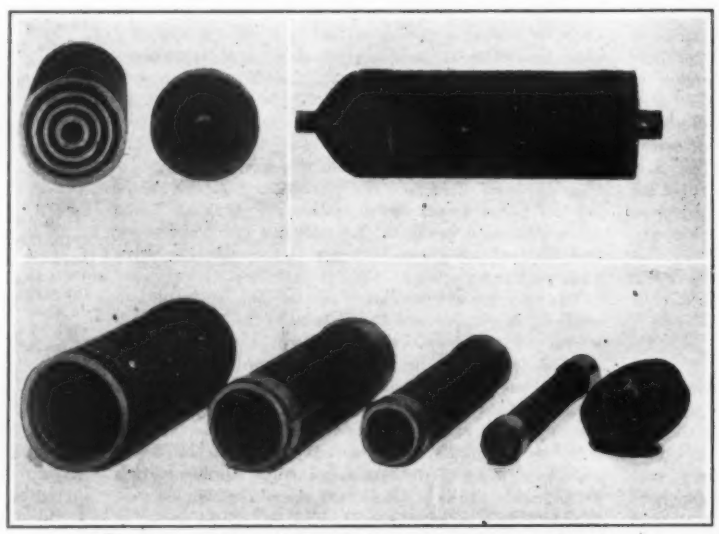

Fig. 14. Cast iron shell with four concentric compartments

be machined to fine limits as regards diameter so that the windage losses may be fairly constant.

When developing these types of shell I was confronted with many difficulties owing to my previous inexperience. To obtain regularity or even certainty with the propellant, involved becoming acquainted with the fundamental principles, such as, that properly to burn a propellant a definite pressure must be generated.

THE PROPELLANT

In a shot-gun the propellant is confined by the inertia of the shot in front of it, and being also confined in other directions, the necessary conditions are present for uniform burning. In my case, however, the conditions were different, as, having abandoned the idea of allowing the end of the cartridge to blow out, it became necessary to provide vents in the side walls. Starting with an ordinary sporting cartridge case, I placed it in a tube or "cartridge container," projecting from the base of the projectile, and provided it with holes. The next difficulty was to determine the size, number, and position of these holes which would avoid one or other of the following objections: (1) Bursting the container; (2) blowing out the end of the cartridge; (3) not igniting the propellant at all, or not with certainty.

It soon became evident that the cartridge container must be made thicker than hydraulic tubing, and that the material used must be of good quality, to avoid splitting open, as the pressure must be at least two tons per square inch. The diameter of the holes must be such that before the side of the cartridge case gives way a sufficient pressure is generated to ensure burning

Fig. 12. Original cast iron shell. Two compartments burst open

the complete charge thoroughly. In addition to the size and number of holes, it was found that the position of the nearest holes to the ignition end had marked effect on the results.

Another difficulty arose from the amount of charge which had to be ignited, and which required a cap with more fulminate of mercury than the normal sporting cartridge cap. This difficulty was at first accentuated by the fact that owing to the wrong shape of the striker nipple, the anvil of the cap was sometimes displaced so as partly to close the flash hole, thus giving short range or miss-fire.

Primers of various sorts and amounts were tried and abandoned.

In the case of the 3-in. gun a No. 12 bore size cartridge is used, and in the 4-in. a No. 4 bore. These cartridges are colored differently, according to the charge they contain, and are varnished so as to make them waterproof. A distinctive mark in the end wad facilitates recognition in the dark, and the end turnover is slightly dented, which ensures a tight fit in the cartridge container, notwithstanding variations in the relative sizes of the cartridges and containers.

Many of the initial difficulties arose from a lack of uniformity in the results. These variations I ultimately found were due to changes in temperature. In warm weather the cap and propellant are more active. I was just on the border line between success and failure, and I frequently found that defects which I had eliminated one day reappeared the next under colder conditions.

These uneven results were very disconcerting and difficult at first to understand. When deciding upon the best kind of propellant, practically all the available smokeless powders were tried, but Nobel's Sporting Ballistite proved in every way the best for the purpose, and was ultimately adopted. Ballistite is a combination of nitro-glycerine with gun-cotton. It is rolled into thin sheets and cut up into squares and coated with graphite. It is very quick burning, leaves no residue, and gives about 27 yard-pounds range per grain. In common with other propellants, its thickness governs the speed of burning, and some difficulty was at one time experienced on account

*The Junior Institution of Engineers. Third Gustave Canet Lecture. Delivered on Monday, June 24th, 1918. Slightly abridged.

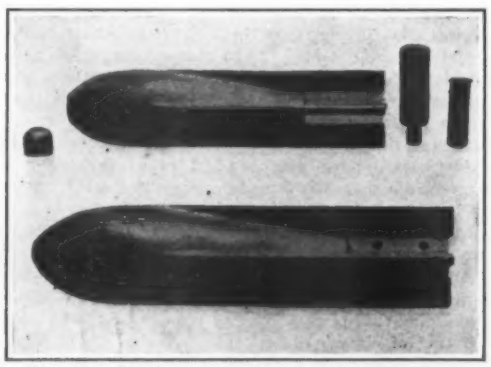

Fig. 15. Cast iron shell with wings—to fly end-on

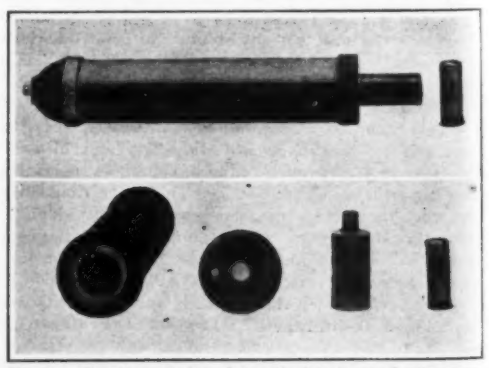

Fig. 16. Cast iron shell and fuse for black powder burster

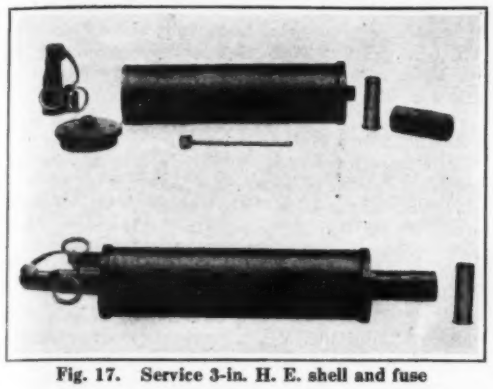

Fig. 17. Service 3-in. H. E. shell and fuse

to the base of the shell, and shaped like a pump leather. It was found that the range was increased by about 30 per cent, but that the accuracy was not improved, probably owing to variations due to the friction set up in the barrel.

THE TIME FUSE

The next problem which required solving was the best means of bursting the shell by some form of time fuse. I started to work, using a short length of projecting Bickford fuse, which should be cut to the required length and lighted at the moment of firing. Bickford time fuse is commercially used for blasting operations, and is a waterproof flexible construction of various makes, with a black powder core woven with strands of hemp. When lighted it burns like a squib, generally at the rate of about ⅜ in. per second, if the end is free for the escape of the products of combustion.

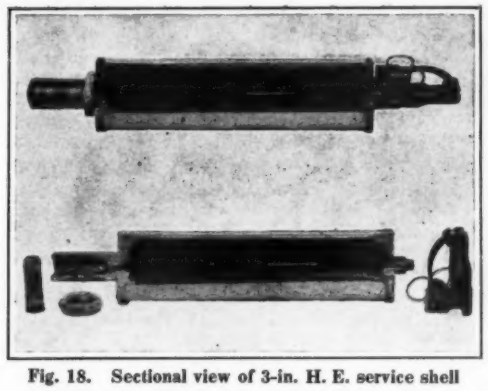

Fig. 18. Sectional view of 3-in. H. E. service shell

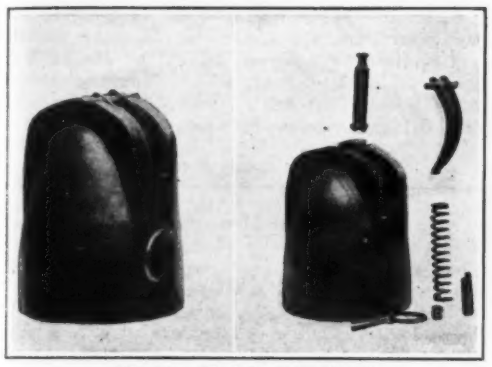

Fig. 19. First time-fuse head

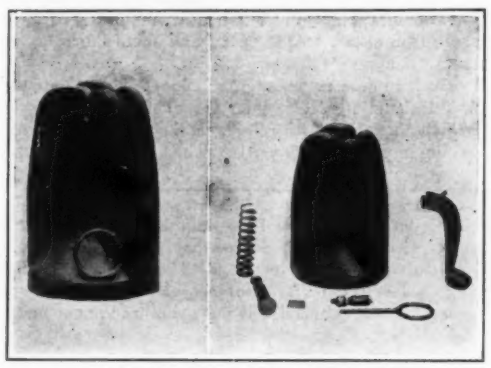

Fig. 20. Second time-fuse head

Fig. 21. Service time-fuse head

of the makers departing slightly from their previous practice in this respect, resulting in the cartridge end blowing out. With ballistite there is very little flash at the muzzle of the gun, even with the original full charge. This is doubtless due to the low muzzle pressure.

When experimenting with black powder, I was struck with the small amount of smoke produced, and this I attributed to the large air chamber in which the powder was burnt. The fouling of the gun, however, made black powder unsuitable.

INCREASED RANGE OF GUN

When the gun was first issued for service a range of about 430 yards was considered sufficient. Under altered fighting conditions, however, it became desirable to increase the range, and this has been done by adding extra charges, made up in the form of rings, which can be slipped over the outside of the cartridge container. The propellant contained in these rings is somewhat thicker than the ballistite in the cartridge, in order that the rate of burning may be so slow as not to add materially to the initial pressure in the base of the gun. The muzzle pressure, however, is considerably increased, as also the flash. The fabric material from which these rings are made tends to foul the gun, and must also be kept dry. An alternative method, which does away with these disadvantages, has been put forward, and is now under consideration.

In order that the shell may slide with sufficient freedom down the barrel, a windage has to be provided which in the case of the 3-in. gun amounts to 2½-hundredths of an inch. This windage reduces the range somewhat, but, as the amount of propellant used is trifling, the loss is not material. Experiments were made using thin flanged copper gas checks attached

Fig. 23. The "Allways" fuse

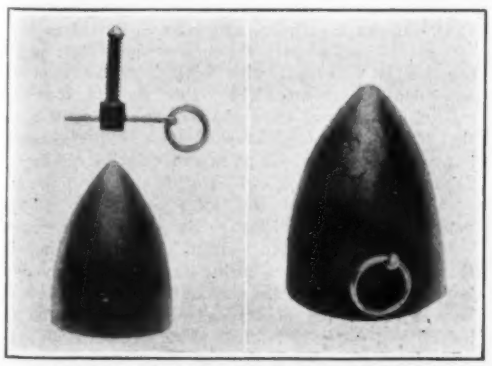

Fig. 22. Final time-fuse head—not adopted

In the case of the cast iron shell shown in Fig. 16 a Bickford fuse is contained in an annular space formed in the base of the shell. One end of the fuse projects into the powder filling in the shell, and the whole was bedded in plaster of paris. A washer, having a hole in it immediately over the Bickford ring, is capable of rotation when the cartridge container is slightly unscrewed. The edge of this washer is marked in seconds relative to a zero mark on the shell flange. A piercing tool is inserted through the hole in the washer when the desired setting is made, thus cutting through the outer fabric of the Bickford fuse, so that on firing the flash of the propellant lights the fuse at the desired spot. Many experiments were made with this arrangement, and some very good results obtained. No prematures were experienced, and with a black powder burster the fragmentation was excellent.

When, however, high explosive is used, it is necessary to adopt a detonator, and a fresh arrangement is necessary. This consists in providing the nose end of the shell with a thin detonator tube projecting into the high explosive filling, into which the detonator and Bickford fuse can be inserted. The upper end of the Bickford fuse is fixed in a chamber containing a cap, which, on being struck, lights the Bickford, the length of which determines the interval which elapses before the detonator explodes.

It should be noted that detonators are occasionally very sensitive, and every precaution should therefore be taken to avoid a premature.

In the arrangement described, the detonator is fired in the direction which still further tends to compress the fulminate of mercury and not to break it up. This is the only safe way to fire a detonator, and the fact that it is crimped on to the Bickford fuse, which is the elastic member which starts it in motion when fired, still further adds to the safety. The method of firing the cap which lights the fuse is shown in Figs. 19 to 22, which show the development of the type of fuse heads.

Fig. 19 shows one of the first heads made, while Fig. 20 shows an improved arrangement.

The mechanism is very similar to that of the Mills hand grenade, viz., a central bolt with a pent up spiral spring coiled round it. The central bolt is maintained in the firing position by a lever which, when uncontrolled, flies outward and releases the central bolt. The end of this lever, however, is maintained in its proper position by a set-back bolt, which, in turn, is kept in position by a coiled spring beneath it. A safety-pin is arranged so that the set-back bolt cannot be displaced and the lever released until the pin is withdrawn. On firing, the inertia of the set-back bolt compresses the spring behind it sufficientlv to allow the lever to be released which then flies off, allowing the central bolt to strike the cap at the end of the Bickford fuse, which is thus lighted.

Fig. 21 shows the service pattern as issued. The mechanism is precisely the same, but the fly-off lever is exposed instead of being shrouded by the body of the fuse, and is therefore liable to be knocked off with rough usage.

Fig. 22 shows a better arrangement, in which a pent-up spring is dispensed with, as also the fly-off lever. It was, however, never adopted, as the design shown on Fig. 21 had already been put in hand. A safety pin passes through the head, and, until it is withdrawn, prevents the central bolt striking the fuse cap or the shell sliding down the gun.

The coil spring round the central bolt is of such strength that on firing, the inertia of the central bolt is sufficient to cause it, by compressing the spring, to

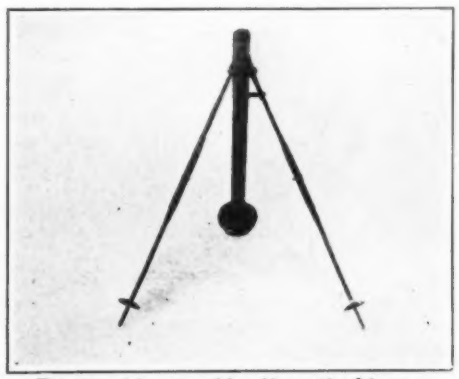

Fig. 24. 2 in. gun with self-contained base

strike the fuse cap. In the case of a partial miss-fire the shock of the discharge is not sufficient to compress the spring, and the cap is therefore not struck. Rough usage in one direction only would tend to ignite the cap, and the strength of the spring is such as to cover all reasonable risks.

There are certain difficulties with the use of the Bickford fuse, one of them being the uncertainty of lighting it by means of the fuse cap, more particularly if damp. This can be got over by coating the end of the fuse with fine black powder, applied with a celluloid solution, such as collodion. In order that the best results may be obtained from the Bickford fuse, a free outlet or vent should be provided for the escape of the products of combustion. The fuse should not be bent about before use, otherwise its speed of burning is increased. The crimping both at the detonator and cap end should be carefully carried out in order not to restrict the outlet of the gases. On the other hand, the crimping should be effectively done in order that the necessary adhesion may be provided between the parts to be set in motion at the moment of firing.

PERCUSSION FUSE

Another form of fuse, called the "Allways" fuse, is shown on Fig. 23. This is a percussion fuse, and, therefore, requires no time setting. The construction of the fuse includes a metal ball confined in a chamber having double conical walls, one wall being formed by a movable member carrying a needle point, which can pierce the detonator or cap, which lights an instantaneous fuse or powder puff in connection with the main detonator, which sets off the high explosive charge. A safety device only allows the ball to function after the projectile has been fired from the gun. As its name implies, this fuse operates when the shell reaches the ground, whatever the position of the shell may be. This fuse was originated by the authorites to obviate the trouble of preparing different lengths of time fuse, and has been recently considerably improved.

At the present moment there are three sizes of Stokes guns, with their appropriate ammunition, in use, viz., 3¼-in., 4¼-in., and 6-in. Fig. 24 shows a 2-in. gun, with a self-contained base arrangement for taking the recoil, which, being hemispherical, facilitates variation in the direction of the barrel without readjustment in the ground. This gun would readily fire 4-lb. projectiles a distance of 200 to 300 yards, and should form a very handy weapon for attack.

The gun was never adopted, but I have thought it of sufficient interest to refer to. The 3¼-in. gun fires a high explosive projectile weighing 10¾ lbs. to a maximum range of 800 yards. The 4¼-in. gun is mostly used for smoke and gas shells of various sizes and weights the maximum range being 1,060 yards with a 26-lb. shell. The 6-in. gun fires 47-lb. high explosive projectiles, the maximum range being 1,420 yards. The shell is of cast iron, with wrought tail wings.

* * *

Having now described the various stages which were passed through when developing the gun and its projectiles, I venture to hope that the history has not been altogether uninteresting. The weapon, as it is now used, seems, in the light of present knowledge, very simple and obvious, but, like most simple things, the arrival at the final stage involved much patient effort, which was rendered more difficult by the apparent lack of data to work upon. It is, however, consoling to know that, in the end, facilities have been provided to our armies and those of our allies at the front, by means of which, with a comparatively short training and experience, results may be obtained which hitherto were not possible.

This result is largely due to the interest taken in my efforts by certain officers, and also to the facilities and support placed at my disposal by Messrs. Ransomes and Rapier, Ltd., Ipswich, who made all the experimental material used. I welcome this opportunity of thanking all those who have helped me to a successful issue.

Electric Arc Welding in Shipbuilding

As previously announced Lloyd's *Register of Shipping* has now issued tentative regulations for the application of electric arc welding to ship construction. The decision to authorize this method in substitution of riveting was only reached after experimental work, extending over several months, and the official account of the investigation, which has now been issued, is of sufficient interest to warrant more detailed reference than it was possible to accord it last week.

It is pointed out that, although electric welding in various forms has been employed for many years for ship repair work, yet, in practice, owing to many factors, its use has been practically confined to those parts of the structure which are not likely to be exposed to important structural stresses. It is only in recent times, commencing from the early days of the war, that appreciable progress has been made in the development of electric welding which would appear to justify the extension of such methods to replace the usual riveted connections of heavy structual work.

Several problems required to be solved before electric welding could be recognized by the leading classification society as suitable for anything like extended use in ship construction.

The aim of the work which has been carried out has been to devise precautions which would secure reliability and regularity of operation in the welding process, and to assist the workmen by improving the means of control over the work. Just as in the case of the application of steel to shipbuilding it was necessary to devise means for the production of the material in large quantities and of constant quality, so also is it necessary that the welding electrodes should be manufactured with the greatest possible degree of uniformity. Reliability of operation is facilitated by adjusting the density of the electric current to the size of electrode used, and further the size of the electrode should reasonably vary directly with the thickness of material to be connected. Research was also necessary to discover means for minimizing the burning of the deposited material in the direction of preventing oxidation. In the early days of welding, the molten electrode was exposed to air throughout the whole time of deposition, and consequently oxidation was more or less certain to occur. With coated metal electrodes burning is reduced to a minimum by the use of a slag which envelops the molten steel and floats on its surface after contact is obtained with the material to be connected. Even in this system skilled workmanship is essential, as the production of a long arc obviously increases the chances of burning. The composition of the material of the electrode in relation to the nature of the steel to be connected is obviously a matter of importance. What the composition is to be can only be gauged by experiment and by wide experience, and it is in devising the physical tests for work of this nature that the greatest difficulties arise. The special problem in shipbuilding is the connection of mild steel containing a percentage of carbon of about .15. This material in the form of plates and section bars has considerable work done to it during the process of manufacture, with the consequence that it possesses a fine structure and a ductility which is uniform in any direction. The finished material may be said to be practically free from fibrous structure. With electric welding, molten metal is attached to the mild steel, and from the extent of the cooling surface the deposited material is rapidly lowered in temperature, with the consequence that the weld tends to become deficient in ductility. The problem therefore is to select the material of the electrode so that the general elastic properties of the structure are not unduly depreciated.

EXPERIMENTS AND RESULTS

The general scope of the experiments included:

(*a*) Determination of modulus of elasticity and approximate elastic limit; (*b*) determination of ultimate strength and ultimate elongation; (*c*) application of alternating stresses with—(1) rotating specimens, (2) stationary test pieces; (*d*) minor tests, such as—(1) cold bending of welds, (2) impact tests of welded specimens; and (*e*) chemical and microscopic analysis.

Tests were carried out on specimens as large as possible, particularly with respect to the static determinations of elasticity, ultimate strength and elongation, some of the test specimens being designed for a total load of just under 300 tons. For alternating stress tests the specimens were relatively small, and bars of welded and unwelded material were tested in pairs, and groups of flat plates, plain, butt, lap welded, and lap riveted were tested together. The results indicate that in a welded plate the extensions in the region of the weld are sensibly the same as for more distant portions of the unwelded plate. The modulus of elasticity of a small test piece, entirely composed of material of the weld, was about 11,700 tons per square inch, as compared with about 13,500 tons for mild steel, and about 12,500 tons for wrought iron. (*a*) The ultimate strength of welded material with small specimens was over 100 per cent. of the strength of the unwelded steel plate for thickness of ½ in., and averaged 90 per cent for plates of ¾ in. and 1 in. in thickness.

In a structure, such as a ship, which is exposed to variations and reversal of stresses, it is extremely important to know whether the material to be used is likely to break down rapidly under such alterations and ranges of stress as are likely to be experienced. The modified Wohler tests employed in the experiments indicate, if considered solely by themselves, that whereas for a given number of alternations mild steel would withstand a range of stress of, say, ± 10.5 tons, the welded material might be expected to fail at about ± 6.5 tons, a figure which is more nearly experienced in ordinary ship construction.

It would appear to be necessary to design the welded joints in such a manner that the amount of work likely to be thrown on the joint is as small as possible, and to meet such a condition a welded joint requires to be either lapped or strapped. Butt welds have a tensile strength varying from 90 to 95 per cent of the tensile strength of the unwelded plate. Lap welds having full fillets on both edges the ultimate strength in tension varies from 70 to 80 per cent. of that of the unwelded material. With a full fillet on one edge and a single run of weld on the other edge the results are very little inferior to those where a full fillet is provided for both edges. In the case of riveted lap joints for plates of about ½ in. in thickness, the specimens averaged about 65 to 70 per cent of the strength of the unperforated plate. The material in the weld appears to be nearly pure iron, and experiments of repetitive stress show that wrought iron bars are likely to fail under a range of stress of perhaps ± 7 to 8 tons as compared with mild steel at ± 10 to 11 tons. The weld has to be deposited electrically and is subject to variation of workmanship. It would therefore be preferable if the material could withstand a range of stress of ± 6.5 tons. The foregoing are the main results of the experimental work, and they have induced the Committee of Lloyd's to adopt as a tentative measure provisional rules for classification of vessels electrically welded.

DETAILS OF CONSTRUCTION

The main features of these regulations are that the system of welding must be approved, that the process of manufacture of electrodes must be such as to ensure reliability and uniformity in the finished article, that operators engaged are specially trained, and efficient supervisors of the work provided. Details of construction of the vessels and of the welds are to be submitted for approval. It has been indicated that butt and edge connections are to be lapped or strapped, and with lapped connections, the breadths of overlaps of butts and seams and the profiles of the weld are to follow regulations which have been embodied in a table, the width of overlap ranging from 2¼ in. with plates .40 in. thick to 3 in. in the case of plates 1 in. in thickness, the throat thicknesses for similar plates ranging from .28 in. to .50 in.

The general character of welds may be briefly summarized. Full welding of the inside and outside edge is prescribed for the butts of shell, deck, and inner bottom plating and butts of longitudinal girders and hatch coamings. Light welding is authorized for the inside edges of shell, deck, and inner bottom plating, butts and edges of bulkhead plating and full welding for the outside edges of this part of the construction. In the case of frames to shell, reverse frames to frames and floors, beams to deck, longitudinal continuous angles, side girders, bars to shell, intercostal plates, floors and inner bottom, and bulkhead stiffeners, tack welding of the inside edge and light welding of the outside edge will be permitted. All bars required to be water-tight are to have continuous welding on both flanges with tack welding at heel of bar. The welded connections of beam, frame, and other brackets must be submitted for special consideration.—*The Engineer.*

Theory of Brownian Movement

Discusses an apparent paradox in the theory of the Brownian movement. Suppose a small sphere to be suspended in a fluid and that its Brownian movement is observed when it has a rather great velocity. May we expect the surrounding fluid to move with the sphere? J. D. van der Waals, Jr., and Miss A. Snethlage [Abs. 985 1916] have recently shown how the answer to this question is connected with Einstein's theory of the Brownian movement. They also showed that the statistical theory of the molecular movement demands that such a common motion does not exist. This theory implies that for a given place and velocity of the suspended sphere and for a given configuration of the surrounding particles of the fluid, equal and opposite velocities of these particles are always equally probable.

There is no objection against Einstein's assumption that a suspended sphere during its Brownian movement imparts its motion to the surrounding fluid in the same way as in the case of a systematic motion under the influence of a constant force.—*Note in Sci. Abstr. on a paper by P. Ehrenfest in K. Akad. Amsterdam.*

Ammonium Nitrate from Coal Gas

SYNTHETIC methods for the recovery and utilization of atmospheric nitrogen have from time to time received a considerable share of attention in these columns, and although some predilection has invariably been shown for those processes that are operated on chemical rather than electrical lines, it must be remembered that the latter methods have, during the past year or so, undergone considerable development. When it was first recognized that processes such as those of Haber and Ostwald could be applied with comparative ease in practice, those who were in touch with the whole question were inclined to think that electrical methods would, from the economic point of view, be unable to stand up against their more modern rivals. This, however, is not altogether the case, and when consideration is given to capital expenditure it is found that the arc processes have a good deal in their favor.

Mr. Kilburn Scott has been working on the problem for some years with the result that he was able to place a considerable amount of interesting information, with figures as to costs, before a recent meeting of the Society of Chemical Industry. Since abundant resources of cheap power are a *sine qua non* of the process it is evidence that the opportunity is one which presents itself to coke oven establishments (where the surplus gas is a residual of comparatively little value), rather than to gasworks proper. Mr. Scott's suggestion is that in view of the erratic supplies of sulphuric acid, the ammonia resulting from distillation should be converted into ammonium nitrate rather than sulphate, and that nitric acid for the purpose could be produced direct from the resources of the works. Before the war, nitrate of ammonia made by the electric process was sold in large quantities at a price ranging from £28 to £30 per ton, and after the war its price is almost sure to be higher than that of any other nitrogen compound owing to the fact that it contains up to 35 per cent of combined nitrogen against 21 per cent in sulphate of ammonia, while it possesses advantages over the other compounds as regards its suitability for exportation. As Mr. Scott points out, nitrate of ammonia is the principal ingredient of most safety mining explosives. The word "safety" is a relative term, expressing the fact that these explosives are safer than dynamite, but on the Continent, before the war, nitrate of ammonia explosives were in fact considered so safe that they were carried on railways at the ordinary rates of transport. There is every prospect, too, that nitrate of ammonia will be used, as it has been in France and Belgium, to a very much greater extent as a fertilizer than has been the case in the past.

PRODUCTION OF NITRIC ACID

Mr. Kilburn Scott has devised a special electric furnace for the production of nitric acid which differs from those used on the Continent for the same purpose in that it is a self-contained three-phase unit. The furnace is fitted with three triangular metal electrodes arranged with intervening walls of refractory material, forming together an inverted conical space having six sides. Air passes into this conical space, and when the furnace is working, the arcs, which are struck between the electrodes where they are near together at the bottom, are extruded into flames by the flow of air. The flames start and stop with each alternation of each phase; thus there are always three flames working together, and to the naked eye, the cone is completely filled. The three currents of the three phases react and rotate very rapidly, the speed of rotation being governed by the frequency of supply, which is usually 50 periods per second. As the particles of air pass upward they come in contact with the rapidly rotating triple arc flames, and the nitrogen and oxygen combine with the formation of nitric oxide.

A point of importance to be borne in mind is that the nitric oxide which is formed when air comes in contact with an electric arc has to be chilled very rapidly, and for this reason there must be a cooling zone in close proximity to the arc flame. Natural movement of the air removes the gas from the hot portion of the flame, but Mr. Scott fits up a boiler to the roof of the furnace to hasten cooling. In this way steam is generated, and the device has proved particularly effective owing to the absorption which occurs in the way of latent heat. Again, in cases where a mixed pressure steam turbine is employed in connection with the generating plant, steam from the boiler may be employed in the turbine so that the combination is worked regeneratively. After making their way through the boiler the gases flow through a heat exchanger, and heat is transferred to the air entering the furnace. It is an advantage to carry preheating in this way to as high a degree as possible, and a temperature of 250 degrees C. may be attained. The normal yield of pure nitric acid per kw. hour is about 50 grams, with 60 grams as a maximum, but with the three-phase furnace considerably higher yields have been obtained.

When the nitric oxide is cooled to below 600 degrees C. it begins to take up more oxygen, and is oxidized to nitrogen peroxide. This process occupies a few minutes, so that it is usual to provide a tower of ample capacity through which the gas may travel slowly. For the purpose of converting the nitrogen peroxide into nitric acid the gas is brought into contact with water in special acid-proof towers filled with tiles, and so arranged that the liquor and gas pass in contra-flow to one another. In this way the acid is worked up to a strength of from 25 to 33 per cent, a sufficient concentration for the manufacture of ammonium nitrate or calcium nitrate compounds. At the end of the acid absorption towers there is a further tower, also filled with tiles, down which a caustic soda solution trickles. In this way the effluent gases are scrubbed with an alkaline solution, while the remaining traces of acid are removed and recovered as a sodium nitrite-nitrate liquor, which is a compound utilized in the manufacture of dyes.

NITRATION OF AMMONIA

The conversion of ammonia into ammonium nitrate is a comparatively simple matter. The dilute nitric acid from the absorption plant is run into a closed iron tank, which contains the ammonia in the form of a 25 per cent solution. The acid is slowly added to a large volume of this liquor, thorough mixture being ensured by the use of an agitator. Cooling coils are provided for carrying off the heat evolved by the reaction. The addition of acid is continued until nearly all the ammonia is taken up, leaving a slightly alkaline solution. This ammonium nitrate solution is then passed through evaporators for the purpose of eliminating the water, and when nearly the whole of the water is driven off the sludge passes along inclined troughs subjected to a "jigging" motion. The nitrate in these troughs forms into small crystals, which are afterward subjected to final drying in a hydro-extractor. As a matter of fact there is no real necessity to concentrate the ammoniacal liquor up to a 25 per cent solution, but the method presents advantages where the liquor may have to be carried any distance. Moreover, when a comparatively strong liquor is employed with an acid of moderate concentration, the resulting product is absolutely pure, which will not be the case when weaker products are utilized.

WORKING COSTS

The question of working costs, and the ability of the arc processs to compete with its modern rivals, is, of course, of primary interest. In discussing the cost of nitric acid one method is to assume it as of 100 per cent. purity, although, as is well known, there is in practice no acid of such concentration. Before the war the cost of Chile saltpeter was in the neighborhood of £10 per ton, and on this basis the cost of pure nitric acid made in the ordinary way from nitrate would be approximately £20 per ton, or about 2.15d. per pound. As a matter of fact, however, the present cost of nitrate of soda is nearer £25 per ton, and when consideration is given to the rise in value of sulphuric acid (a necessary auxiliary in the manufacture of nitric acid), labor, and other items, it may be estimated that the present value of nitric acid is upward of £50 per ton. As regards his electrical process Mr. Scott assumes that a figure of ⅛d. per unit is a fair one to take for energy, and he points out that there are in this country electro-chemical factories which have been supplied at less than this figure for some years. The yield of pure nitric acid which may be expected from the three-phase furnace is 66 grams per kw. hour, or 200 grams of 33 per cent acid, the calculated cost of the pure acid working out at £13 10s. per ton, or about 1.44d. per pound. As against this Mr. Scott states that nitric acid made by a combination of the cyanamide and oxidation processes would cost at least £25 per ton of 100 per cent strength.

There is, however, a good deal of uncertainty about the figures given as to the working costs of all these new processes, and it is interesting to put on record the opinion of Dr. Maxted, who followed Mr. Scott at the meeting of the Society of Chemical Industry with a paper dealing exhaustively with the synthesis of ammonia and its oxidation to nitric acid. Dr. Maxted stated somewhat emphatically that under normal conditions of working the cost of synthetic ammonia made by the Haber process would be from £10 to £12 per ton (and by the Ostwald process it may be assumed that the cost of the nitric acid is about half that of the original ammonia used), and after discussing the costs of other processes he expressed the opinion that so far as power and raw materials are concerned, the formation of ammonia by direct synthesis is a process more than twice as efficient as the cyanamide process, and more than six times as efficient as the arc process. In fact, despite various charges which are certainly more material than in the rival processes, the direct synthesis of ammonia (coupled, if necessary, with subsequent oxidation), presents by far the most economical means of effecting the fixation of atmospheric nitrogen at present known, and if only in virtue of the urgent need of the land for cheap, abundant, and non-seaborne fertilizers it is deserving of every consideration from the standpoint of national economy.

In view of the fact that the Hausser process provides another but essentially different means of producing nitric acid from coal gas or coke-oven gas, it will be interesting to look forward to the time when the two systems will be in a position to be compared on a working scale in this country. It is generally known that the Hausser process has been thoroughly investigated by one of the committees dealing with this subject, and the knowledge now accumulated would seem to warrant a practical trial. In the way of capital expenditure there should be little to choose between the two methods. For the arc process Mr. Scott estimates that a 1,000 kw. installation driven by surplus gas would entail an expenditure of some £28,000, and that this plant, if expectations were fulfilled, would produce an annual revenue of rather more than £4,000. The Hausser explosion apparatus is relatively simple, and that very appreciable item, the provision of expensive catalysts common to the synthetic and oxidation plants, is eliminated.—*London Times Engineering Supplement.*

An Aspect of Light, Shade, and Color in Modern Warfare

THE subject was treated from the viewpoint of the theory and practice of camouflage. Camouflage is a modern term for an old art which has been practiced by nature long before the advent of man. Animal coloration is an important factor in the Darwin theory of evolution or of the survival of the fittest. In this great war the practice of camouflage is highly developed and we must consider an aspect of the science of light, color and vision which is not ordinarily considered by the artist. Excellent work has been done on animal coloration and excellent analyses are available. One of the chief principles of animal coloration is broken color and pattern. An object of solid color can not be easily concealed in natural environments. Natural camouflage involves general hue, pattern, countershading, mimicry, mobile color and pattern, etc. Black areas on animals may simulate shadows. Pattern may be used to simulate the background, to alter the appearance of the outline of the animal, to bewilder the enemy, etc. Most animals are counter-shaded, being of higher reflection—factor underneath to compensate for the lower illumination intensities on these areas. Some animals imitate by their form or posture inanimate objects or other animals that are dangerous. Some animals change their coloring with the season, others almost momentarily. Thus from nature the camoufleur may learn much and the lighting expert is equipped with knowledge of other scientific aspects.

About fifty lantern slides illustrated the aspects of color science involved, the variation in nature's lighting, the practice of camouflage, the theory and practice of aerial photography. On overcast days the problem is simplified but on sunny days the shadows present difficulties which are met by effecting other "shadows" and therefore confusion, by special contours of objects in order to minimize shadows, and by other expedients.

The artist usually deals with color from the subjective standpoint and the importance of imitating the surroundings by means of pigments which are spectrally the same was emphasized. For example, the chlorophyll green of vegetation appears green but exhibits a deep red band in its spectrum. A green paint which would ordinarily be mixed to match this green subjectively would not exhibit the red band spectrally. When such an artificial green is viewed through a deep purple filter (such as methyl violet) or a dichroic green filter it appears a dark gray but through these filters the chlorophyll is a brilliant red. By means of spectral analysis, pigments can be mixed to simulate the desired color spectrally. Attention was directed to experiments made by the speaker before the war on the use of filters for defeating camouflage or for revealing objects such as soldiers by augmenting the contrast. By means of filters, we apparently produce eyes which in effect are the same as though they differed in spectral sensibility. The many photographic plates of different spectral sensibilities also emphasize the importance of the spectral viewpoint toward camouflage. The aspects which the earth presents when viewed at heights as great as 2 miles were described from personal experience in studying this phase. Marine camouflage and other aspects were also treated. The address emphasized the extending breadth of the field for the lighting expert as he extends his knowledge of the facts of light, vision, color, and the appearances of objects as influenced by their coloring and by the distribution and quality of light.—*Abstract of an address by M. Luckiesh, delivered before the New York Section.*

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The pods are opened with a sharp knife and the beans removed

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The "cocoa dance": Women tread the dry beans to remove the adhering pulp

Chocolate and Cocoa

Valuable Foods Extensively Used By Soldiers of Many Armies

A VARIETY of food that occupies an important place in the supplies of every modern army is chocolate, as it supplies in a very compact form that can be carried by the individual soldier both a food and a stimulant, thus constituting an extremely valuable ration, particularly for troops that are temporarily out of touch with their base of supplies.

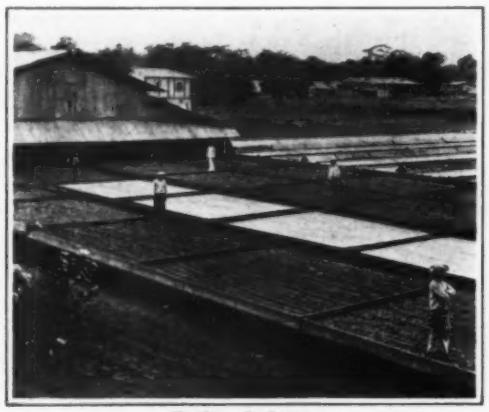
The stimulating property of chocolate, which is one of its most important characteristics, is due to the presence of a small percentage of Theobromine, an alkiloid which has a similar physical property to the caffeine of coffee and tea, and is also closely related to the alkaloids found in maté and kola. The value of these latter beverages lies practically exclusively in their stimulating alkaloids; but whereas these are simply infusions, in a cup of chocolate we also get a considerable quantity of fat, starch and albuminoid matter that constitutes a food as well. This is shown by the following analysis of the cocoa bean, from which chocolate is prepared:

	Per cent.
Fat	50
Starch	10
Albuminoids	20
Water	12
Cellulose	2
Mineral matter	4
Theobromine	2
Coloring matter	Trace
	100

The name, cocoa, is the result of a confusion in spelling, for the true word is cacao, and the coconut tree, from which it is sometimes supposed that the cocoa bean is derived, is an altogether different variety from the cacao. The cacao tree is supposed to have been originally a native of regions along the Caribbean Sea, and particularly of the islands; but its cultivation has spread throughout the tropical regions, and is now also grown in Africa, Ceylon, Java, and India, as well as in Venezuela, Ecudaor and other parts of South America. Probably more cacao is produced in Ecuador than any other single region; but the British island of Trinidad is a very large producer, as are also most of the others of the larger Leeward Islands, Martinique, Guadaloupe, Dominica, St. Lucia and Jamaica.

Under cultivation the tree from which the cacao bean is obtained seldom grows higher than 25 feet, although in its wild state much taller trees are frequently found. The seeds of the tree are borne in pods, which are irregular and angular in shape, much resembling some forms of cucumbers. These pods measure from nine inches to a foot in length, and about half as much in diameter. In color, these pods are green when young, but later on become a dark yellow, or a yellowish brown, with a thick, tough rind. The pods are filled with closely packed "beans" or seeds, embedded in a mass of cellular tissue, or pulp, of a mucilagenous character. Each pod will contain from 20 to 60 seeds of about the size of an ordinary almond, whitish in color when fresh, and with a disagreeable, bitter taste. The fruit requires about four months for ripening, and although the tree goes on bearing throughout the year, harvesting is usually confined to the early spring, although the time varies in different countries.

In harvesting, the workman carefully selects the ripe pods, which he cuts from the trees by means of a long pole having a knife, or two sharp prongs attached to its end. These pods are allowed to lie in a heap for 24 hours, when they are cut open with a sharp knife, and the pulpy contents, carrying the seeds, are extracted and piled in heaps for fermentation. These heaps are covered with leaves; or the sweating may be carried on in barrels or boxes lined with banana leaves. This fermentation process requires from one to twelve days and extreme care is necessary that it is not too violent, as too high a



Drying platforms

temperature would seriously affect the flavor. To prevent this the heaps are closely watched, and the seeds turned over at least once a day. The process of sweating destroys the mucilage of the pulp, and at the same time the seeds lose some of their bitter taste. In some markets the strong, bitter flavor is preferred, and in such cases the fermentation process is omitted.

After fermentation the beans are sometimes washed, to remove the mucilaginous matter of the pulp; but in any case they must be dried, and this is accomplished by spreading them on large platforms, where they dry in the sun, attendants turning them over occasionally. After drying it is customary, in some districts, to tread the beans with the feet, to remove the adhering pulp, and this process is seen in one of the accompanying illustrations which shows the "Cocoa Dance."

The beans are now ready for shipment to the manufacturer; and on arrival at the factory the first process is sorting, which has for its object the removal of imperfect beans, and foreign substances, and particularly the grading of the beans according to size to insure uniformity in roasting. Roasting is done in revolving metal drums, where the beans are heated to a temperature between 260 and 280 degrees for the purpose of developing the aroma and flavor of the chocolate or cocoa to be made. Roasting also eliminates some of the bitter constituents of the bean, besides partially converting the starch into dextrine, thus making the product more easily digestible.

The beans are now ground, and the shells and germs, are removed and if cocoa is to be made the ground beans are pressed in heated hydraulic presses to remove some of the fat, and this is the well known cocoa butter, which is widely employed for pharmaceutical purposes. After the fat has been extracted the remaining material is ground to the fine powder that we see in the ordinary commercial cocoa. To make chocolate the ground beans are further ground until a perfectly homogeneous pasty mass is obtained. This is the ordinary unsweetened chocolate; but sugar, various flavoring and starchy matters may be added by incorporating them during the final grinding process. Sometimes an additional amount of the cocoa butter, obtained from the manufacture of cocoa, is put in the mixture, especially when the chocolate is intended for making confectionary. The well known milk chocolate is made in the same manner as indicated above, but with the addition of milk powder, and suitable flavoring matter.

The shells separated from the cracked beans are saved, and after suitable preparation are marketed either as "cocoa shells," or under the name of "broma," which are preferred by many people who have weak digestion, as this product contains only a very small percentage of fat food elements, but does furnish some theobromine, the stimulating element. These shells have also been utilized as a cattle food, although it is obvious that its food value is unappreciable.

The above is but an outline of the process of manufacture as followed in this country. On the Continent, and particularly in Holland, different processes are followed, among which is the Dutch process in which the cocoa is treated with alkalis, for the purpose of rendering the product more easily digestible; but many people think that the delicate natural flavor and aroma is diminished by such chemical treatment.

As has been said before, cocoa furnishes in a compact and concentrated form both a stimulant and a food, and it is therefore a most valuable element for the rations of soldiers, and particularly as an emergency ration. For this latter purpose chocolate is held in high esteem in many of the foreign armies, but in this country its valuable qualities have apparently been overlooked.

Composition of Cognacs and Wine Distillates

ANALYSES of French and German wine distillates show that the former now more nearly resemble the latter in composition, particularly as regards the amount of higher alcohols. While the French products used to contain from 150 to 300 mgrms. of higher alcohols per 100 c. c. of absolute alcohol, the quantity now rarely exceeds 80 mgrms. Of twenty-six German cognacs examined, only five contained more than 100 mgrms. of higher alcohols per 100 c.c. of alcohol; in the remainder of the samples the quantity varied from 20 to 79.8 mgrms. Three out of five samples of French cognac contained less than 100 mgrms. of higher alcohols. —*Note in Sci. Abats. on an article by W. D. Bancroft, in J. Phys. Chem.*

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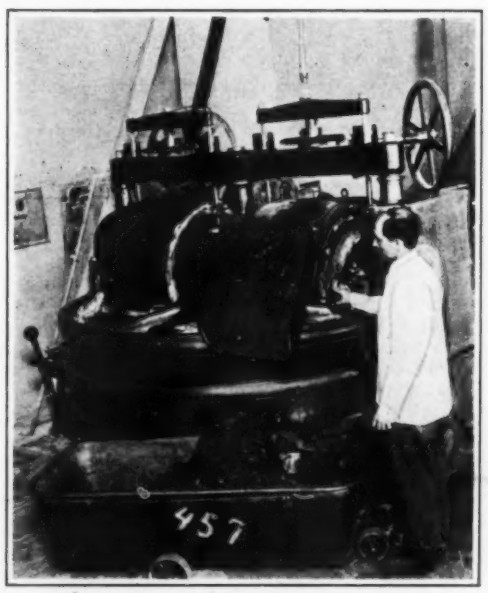
Sorting the beans

Emptying the beans from the roaster

The Chemistry and Metallography of Aluminium

Two of the papers brought before a meeting of the Faraday Society, dealt with aluminium. The first, by Mr. John G. Rodin, F. I. C., "Contributions to the Chemistry of Aluminium and its Alloys," was largely analytical in character. As chemist of Messrs. H. I. Raphael's Refinery, Mr. Rhodin has had to analyze tons of aluminium scrap and swarf (turnings, etc.), and as these alloys consist practically of aluminium with low or high percentages of zinc and copper, he successfully attempted to sort the metal by means of a gravity test. He observed that alloys containing from 4 per cent up to 60 per cent of these other two metals showed densities increasing from 2.767 up to 3.519. As the aluminium percentage decreased, the rate of this rise in density was first rapid, diminishing afterward; but Mr. Rhodin's data were hardly sufficient to support the inflection-point in his density curve at about 76 per cent Al, to which he drew attention. As regards the chemical analysis of Al and its alloys he made the important statement that he had found a direct method of determining the metallic aluminium. So far there is no practical, direct method known, and that is all the more regrettable since the indirect methods count all that is not copper, zinc, silicon, etc., in the alloys as metallic aluminium, while a good deal of the assumed aluminium may really be present as oxide; there is always plenty of oxide in scrap in particular, but the determination of its percentage is very difficult. Mr. Rhodin states that he can dissolve all the metallic aluminium in an alloy by caustic soda of 10 per cent; what remains insoluble consists of alumina and the other metals; the residue is dissolved in nitric acid, and the solution is further analyzed in the usual way. The residue might still contain some metallic aluminium, and oxide or basic carbonate might be formed during the process of dissolution; but he had not overlooked that. Such a method would, as Dr. Rosenhain pointed out, be of very great value, but he had his doubts; while Dr. Seligman, Dr. Gwyer and others criticized the statements as inacceptable. Mr. Rhodin further considers that there are two aluminium oxides, a suboxide Al_4O, and the oxide Al_4O_4; the latter he believes to be produced on burning the metal in air, and to form a solid solution with the metal. Mr. Rhodin claimed to have some evidence of having isolated Al_4O_4; the oxide is generally given the formula Al_2O_4. It cannot be said, however, that his analyses were very convincing; they were all brought up to the correct total 100.0 by ascribing the difference to copper or zinc, etc., which should have been determined separately. Thus there is no check on his analyses. On the other hand, Mr. Gertin and others pointed out that Mr. Rhodin's many analyses and other tests were concordant and had never been questioned by the interested parties. It is to be hoped that the matter will further be investigated. Mr. Rhodin is also engaged in scientific heat tests which he performs with the aid of a calorimeter, the copper vessel of which is lowered into a vacuum vessel quite 2 feet in height. Some interesting remarks on aluminium were made during the discussion Dr. Rosenhain said that a certain percentage of iron in the aluminium, ½ per cent, and even 2 per cent, was not at all a disadvantage, and Mr. C. Vautin showed an experiment with a blackish aluminium powder, which contained about 70 per cent of metallic aluminium. When a small heap of this powder was placed on an iron tray, and lighted with an ordinary match—the granulated aluminium thermit of Goldschmidt requires lighting with a "cherry" of some peroxide—it first glowed like charcoal, and then began to burn with an intense glow, but very quietly. Mr. Vautin suggested that the first glow probably produced the suboxide Al_4O of Mr. Rhodin which subsequently burned to oxide or peroxide. —*Engineering.*

Cocoa grinding



Sweet chocolate mixing machine

Laundry Dries Fruit

"A short time ago it was not thought possible that a steam laundry could be of use for anything but making a man look his best in starched linen, or a woman look pleasant with the realization of the work she had escaped by sending the family wash to the laundry instead of doing it herself," said the *News*, of Northfield, Minn., in a recent issue.

"But all of that has been changed during these war times, and the laundry proprietor has been thinking he would have to move his residence to his place of business if things kept on the way they have for several weeks past.

"Since it was discovered that the drying facilities of the laundry could be utilized for drying vegetables and fruit, Manager Jay Davison, of the Northfield Cooperative Laundry, has been swamped with this extra business, which means much extra night work.

"The vegetables and fruit handled were principally corn, beans and apples. Everything is prepared before it is brought to the laundry, where it is placed on large trays holding about ten pounds each. The capacity of the dryer is about 150 pounds. The trays are placed in the dryer at night and removed in the morning. Steam must be kept up for a while during the evening, and the caretaker must be on hand for a few hours to look after the fruit or vegetables, so they will dry properly.

"Each lot is weighed as it is brought in and is kept separate, a charge of one cent a pound being made on the basis of this weight."—*National Laundry Journal.*

The Alsatian Potash Deposits

The restoration of Alsace to France would put French industry in possession of the valuable deposits of potassium chloride discovered in 1904. Those rich deposits cover an area of 7 square miles to the northwest of Mulhouse. The estimated available quantity is 300,000,000 tons. They could be made to yield an annual output of 800,000 tons, at a low working cost. Already 15 shafts have been sunk; but production has been hindered by legal restrictions arising out of the German potash laws.

The Mechanism of the Setting Process in Plaster and Cement*

By Cecil H. Desch, D.Sc., Ph.D. (University of Glasgow)

ALTHOUGH the use of calcareous cements dates from a very early period of human history, and has attained to so high a development in modern times as to have given rise to an industry of the greatest importance, our knowledge of the scientific nature of the materials and processes involved is even yet imperfect, in spite of many excellent investigations covering various parts of the subject. It is convenient, in a review of our present knowledge, to distinguish between the plasters and simple chemical cements, such as the magnesia cements on the one hand, and the lime mortars, Roman and Portland cements, and similar products, on the other. The chemistry of the substances of the first group is now fairly well known, although the plasters manufactured from gypsum have proved to be unexpectedly complex, and there is little doubt that a correct explanation of the principal features of the setting process has been given. The case is different when we turn to the second group. It is only very recently that definite information as to the chemical constituents of Portland cement clinker has been obtained, and even now some points remain in dispute, while two distinct explanations of the setting process have been given, and the evidence in favor of either is by no means conclusive. In the present paper an attempt is made to examine these hypotheses and the evidence adduced in their support, and to indicate the nature of the observed discrepancies. The plasters are first considered on account of their relative simplicity. A short section then follows on the magnesia and similar cements, and the third section is devoted to the setting of lime mortars and the complex cements.

I.—PLASTER OF PARIS AND GYPSUM CEMENTS

It was shown by Lavoisier in 1765[1] that the setting of plaster of Paris was essentually a process of recombination of the dehydrated gypsum with the water of which it had been deprived in the process of "burning," and that the strength of the mass after setting was the result of the formation of a confused mass of interlacing crystals. The mechanism of the process was not explained until 1871, when Prof. H. le Chatelier[2] showed that the hemihydrate, $2CaSO_4, H_2O$, readily dissolves in water, forming an unstable solution which is supersaturated in respect to the dihydrate, $CaSO_4, 2H_2O$. Any particles of the latter salt which may be present, probably in the form of unburnt particles of the original gypsum, act as nuclei, and set up crystallization of the stable dihydrate. It is characteristic of crystals separating from strongly supersaturated solutions that they tend to grow in radial fashion about the nucleus. When the nuclei are sufficiently near to one another, the radiating needles of neighboring groups interlock, and a mass possessing considerable mechanical strength is obtained, which can only be broken across by breaking the individual crystals. That such a supersaturated solution is actually formed is not only proved by microscopical examination, but was shown by an experiment due to Marignac,[3] who shook ground plaster of Paris with water and filtered after a short interval. The filtrate was five times as concentrated as a saturated solution of gypsum at the same temperature, but it soon became turbid and deposited crystals of the dihydrate. In the ordinary setting of plaster the quantity of water is so small as to be capable of dissolving only a minute fraction of the calcium sulphate, but it is sufficient to form a layer of supersaturated solution around each particle of the hemihydrate, and when this layer deposits its excess of dihydrate the remaining water is available for the solution of a further quantity.

It is certain that the above statement corresponds closely with the main facts of the setting of plaster of Paris of the composition $2CaSO_4, H_2O$, as prepared by any of the usual technical methods. So far as the writer is aware, only one attempt has been made to explain the setting of plaster as a colloidal process. Rohland[4] has suggested that the water is taken into solution in the salt in a colloidal form, and has extended the same explanation to the caking of other salts when powdered and moistened, but the statement is not supported by evidence, and has not been accepted by others.

There are, however, certain facts which indicate that the setting process is not quite simple. It was observed by Cloez[5] that the heat evolved during the setting appears at two different stages, the initial rise of temperature on mixing plaster with water being followed by a stationary period and then again by a rise of temperature. Moreover, the density of the hydrated plaster is different from that which might be expected from the known properties of calcium sulphate and its hydrates. The hemihydrate has a density of 2.75 and the dihydrate of 2.32, and a calculation shows that the latter compound is formed from its components with a contraction of 7 per cent, while in practice an expansion is observed, and it is in fact on account of this property that plaster of Paris finds its application in the making of casts, the expansion enabling it to fill the mold completely, and therefore to take an impression sharply. The setting is found to be accompanied by a contraction, followed by a smaller expansion. The experiments of Davis[6] led him to the conclusion that the crystals of the dihydrate which at first separate are not identical with gypsum, but consist of a second, rhombic modification, which subsequently passes into the stable form. It may also be remarked that a part at least of the expansion is only apparent, and is due to the thrusting apart of the growing crystals, producing a porous mass. This effect is common in the growth of crystals from a supersaturated solution, and its existence is obvious from the familiar porosity of a mass of hardened plaster.

The setting of the various kinds of flooring plaster, consisting largely of soluble anhydrite, is in all probability of a quite similar character, and differs from that of plaster of Paris only in regard to velocity. The addition of other salts may also bring about great changes in the rate of hydration and crystallization of calcium sulphate, potassium sulphate, for instance, accelerating the process and borax retarding it. Rohland has shown[7] that the accelerators are substances which increase the solubility of gypsum, and the retarders are those which diminish the solubility. Colloidal substances may delay the setting considerably, and these facts are made use of in the preparation of many technical plasters.

II.—SUBSTANCES THE SETTING OF WHICH RESEMBLES THAT OF PLASTER

It was also shown by Le Chatelier that other substances which are capable of forming unstable supersaturated solutions will set in the same manner as plaster of Paris. Thus, anhydrous sodium sulphate dissolves readily in water, and if precautions are taken to prevent too rapid solution and consequent rise of temperature, a highly concentrated solution may be prepared at practically constant temperature. This solution is unstable, and the hydrate separates in characteristic interlocking masses of crystals.

Various cements composed of a mixture of an insoluble metallic oxide and a solution of the chloride of some similar salt of the same metal are in technical use. For example, a mixture of zinc oxide with a concentrated solution of zinc chloride yields a strongly supersaturated solution, from which the oxychloride slowly crystallizes. Magnesium oxychloride, prepared in a similar manner, forms the basis of many cements, and may be assumed to set by a process of crystallization, although Kallauner [8] considers that the case with which the chlorides is extracted from the solid mass by means of alcohol, and the fact that the free magnesia in the mixture cannot be completely converted into carbonate by carbon dioxide, points to the formation of a solid solution of hydroxide and chloride rather than of a definite oxychloride. A microscopical study of the setting process does not appear to have been made, although it would have some interest in relation to the problem of the dental cements, some of which have an analogous constitution.

Barium metasilicate is another salt which forms supersaturated solutions and is capable of setting when mixed with a small proportion of water. The product is the crystalline hydrated salt $BaSiO_3, 6H_2O$. The orthosilicate undergoes hydrolysis, forming the hydrated metasilicate, $Ba_2SiO_4 + 15H_2O = BaSiO_3, 6H_2O + Ba(OH)_2, 8H_2O$. Owing to the comparatively great solubility of the silicate the setting resembles that of plaster, and the mechanical strength of the product is not comparable with that of a hydraulic cement, although in the case of the orthosilicate the chemical reaction is quite similar to that which constitutes the principal part of the hydration of a Portland cement. The product is crystalline, and consists of interlocking bunches of needles.

III.—LIME, MORTAR, AND CEMENTS OF THE PORTLAND CLASS

The hardening of a simple lime mortar, composed only of slaked lime and sand with water, is a mere process of desiccation. The calcium hydroxide forms an apparently structureless mass, which may be either colloidal or minutely crystalline, and the cohesion of this mass furnished the necessary strength. The sand merely prevents the cracking which would otherwise take place during the contraction on drying, by sub-dividing the lime into thin layers. As time goes on the calcium hydroxide may recrystallize to a certain extent, while those portions of the mass which come into contact with the atmosphere may be converted into the crystalline carbonate, but neither of these changes is essential to the hardening of the cement. There is no chemical reaction between the lime and the sand. On the other hand, when pozzolanic substances are added to the mortar, such as the volcanic earths of the Mediterranean which were used by the Greeks and Romans, the trass and ground tiles which were employed by the Romans in more northern regions, or the burnt brick and ballast added to this day in India, a chemical reaction takes place between the lime and the active or soluble silica which is the essential constituent of all pozzolanic materials, and calcium metasilicate is formed.

Portland cement is a more complex material. The constitution of the clinker has been established by the brilliant investigations of the Geophysical Laboratory staff at Washington. The compounds which are or may be present are tricalcium silicate, $3CaO,SiO_2$; calcium orthosilicate, $2CaO,SiO_2$; tricalcium aluminate, $3CaO,Al_2O_3$; pentacalcium trialuminate, $5CaO, 3Al_2O_3$; and free lime, CaO[9]. Campbell has recently given reasons for believing[10] that tricalcium aluminate is rather to be regarded as a solid solution of lime in the pentacalcium trialuminate, but this does not materially affect the present problem. Not more than three of the abovementioned compounds can be simultaneously present in the clinker in a state of equilibrium, but since the components do not reach the temperature of fusion during the process of manufacture, it is actually possible for small quantities of one or more additional constituents to occur in commercial clinker. It does not appear, however, that clinker made in a rotary kiln departs very widely from the state of equilibrium.

An examination of the ternary equilibrium diagram shows that the clinker will contain a ternary eutectic, there being two such eutectics within the usual range of the composition of clinker. The microscopical examination of transparent sections of clinker does not reveal the presence of any eutectic, but this is simply due to the minuteness of the structure, much overlapping occurring even within the thickness of a thin section. When, however, the specimen is polished on one surface only and lightly etched, as in the examination of metals, the eutectic structure is clearly revealed. The writer has published one such photograh[11], and Mr. T. Hattori, working in the writer's laboratory, has since obtained very beautiful eutectic structure of Japanese clinker. The calcium aluminate which is chiefly present as a constituent of this eutectic is consequently in a finely divided form, and therefore in a condition to react readily with water.

According to the explanation of the setting process put forward by Le Chatelier in 1887 the ground cement reacts with water in such a way that the silicates and aluminates are hydrolysed, the staple compounds being the hydrated metasilicate, $CaSiO_3, 2.5H_2O$, and a hydrated tetracalcium aluminate, $4CaO,Al_2O_3,12H_2O$, the excess of lime liberated by the hydrolysis forming calcium hydroxide. Microscopical examination of the reactions of the constituents with water led to the conclusion that the process was strictly analogous with that of the setting of plaster, an unstable supersaturated solution of the basic silicate, for example, being formed initially, followed by rapid crystallization of the stable phase in the form of radiating needles. In reference to this it should be remarked that the process is largely dependent on the ratio between solid and water, and that in hydration experiments on a microscope slide the quantity of water used is relatively much larger than

*A contribution to a General Discussion on "The Setting of Cements and Plasters," held by the Faraday Society, republished from the *Chemical News*.

[1] Lavoisier, "Œuvres Compl." III, 122.

[2] Thèse de doctorat, 1887, "Recherches expèrimentales sur la Constitution des Mortiers Hydrauliques," Paris, 1904.

[3] C. Marignac, *Arch. Sci. Phys. Nat.*, Geneva, 1873, XLVIII, 120.

[4] P. Rohland, *Kolloid, Zeit.*, 1913, XIII, 61.

[5] C. Cloez, *Bull. Soc. Chim.*, 1903 (3), XXIX, 171.

[6] W. A. Davis, *Journ. Soc. Chem. Ind.*, 1907, XXVI, 727.

[7] *Zeit. Elektrochem*, 1908, XIV, 421.

[8] O. Kallauner, *Chem. Zeit.*, 1909, XXXIII, 871.

[9] G. A. Rankin and F. E. Wright, *Amer. Journ. Sci.*, (4) XXXIX, 1.

[10] E. D. Campbell, *Jour. Ind. Eng. Chem.*, 1917, IX, 943.

[11] "The Chemistry and Testing of Cement," London, 1911. Plate I.

in the gaging of cement in practice, and that this fact probably accounts for certain discrepancies recorded by different observers.

The alternative hypothesis was proposed by W. Michaelis in 1893,[12] and expanded in a later paper.[13] On this view, while the chemical reactions assumed are those which were shown to take place by Le Chatelier, the physical conditions are supposed to be different. The hydrated metasilicate is considered to form, not a mass of radiating crystals, but a gelatinous mass or gel, the gradual dehydration of which brings about the hardening of the cement with time. The aluminate crystallizes much more readily than the silicate; but even this is regarded as forming a gel when the solution is sufficiently supersaturated—that is when the quantity of water is small, as is the case in the practical utilization of cement. The presence of gelatinous material at an early stage of the setting process is readily observed. It has been photographed by Stern,[14] and the increase of size of the cement particles by absorption of water and consequent swelling of the gelatinous sheath which forms around them has been described by Ambronn,[15] and may be readily confirmed. According to Colony,[16] a reaction subsequently takes place between this early gelatinous material and the remaining constituents of the cement, and a secondary amorphous product is formed, the desiccation of which is the cause of the hardening. At a later stage crystals of calcium hydroxide, calcite, and zeolites make their appearance.[17]

An attempt to distinguish between the various possible colloidal products has been made by Keisermann,[18] using the method of staining with organic dyes. The results indicate that the gelatinous sheath consists of calcium metasilicates, which compound also occurs in the form of small needles, while the calcine hydroxide and aluminate assume the crystalline form. These staining results with colloids depend largely on the concentrations of the substances concerned, and the writer, possibly not working under precisely similar conditions, has not succeeded in confirming all of Keisermann's results. The dependence of the observations of the size of grain has been pointed out by Wetzel.[19] Other experiments in which stains were used led Blumenthal to the conclusion[20] that the metasilicate and aluminate were first formed in a crystalline condition, so that the cement sat like plaster, but that a colloidal gelatinous silicate was subsequently formed, and strengthened the mass by binding the crystals together and filling the pores.

The process of setting of the individual constituents, as well as of commercial clinker and artificial mixtures, has been examined in great detail in the laboratories of the U. S. Bureau of Standards.[21-22] The staining method has been applied as a means of identification, and the hydration has been followed under various conditions of temperature and proportion of water. The general conclusion is that the initial set is due to the hydration of the aluminates, and that the only stable hydrated aluminate is the tricalcium salt, the water content of which is variable. Either the 5.3 compound or monocalcium aluminate, if present, undergoes hydrolysis, and the tricalcium salt is formed together with free alumina, the latter separating in a colloidal hydrate form. In presence of an excess of water the product may be crystalline, as in Le Chatelier's original experiments, but with a restricted supply of water an impervious layer of the amorphous material may be formed, retarding the further action of water. The silicates are hydrated much more slowly, the products being calcium hydroxide and an amorphous jelly of hydrated silicate. The hydroxide may be crystalline or amorphous, according to the concentration and to the rate of hydration. The hydrolysis of the silicates is even considered to proceed so far that gelatinous silica is liberated.[23] The subsequent conversion of a part of the gelatinous mass into crystals is considered to result rather in a loss than in a gain of strength.

It would appear that conclusions based on the examination of mixtures of ground material with water on a microscope slide must not be applied indiscriminately to the conditions of actual practice. The ratio of water to salts is of the utmost importance in determing the nature of the products, although the chemical reactions may be the same in both cases. An attempt has been made by Von Weimarn[24] to show that the passage from the colloidal to the crystalline condition is a continuous one, and that the difference consists only in a difference of size of the particles. This may be accepted in the sense of considering colloidal materials as being in such a fine state of division that the surface forces are comparable in their effect with those which depend on mass. It is then not difficult to understand that the degree of supersaturation of the solution may determine whether the product which separates shall have a definite crystalline form or shall be in the ordinary sense amorphous. The real nature of the colloidal condition has been unnecessarily obscured by the barbarous terminology which has been adopted by so many writers on the chemistry of colloids, and especially by the school of W. Ostwald.

A final reference should be made to the action of catalysts on the process of setting. The subject has not been sufficiently investigated, and affords a promising field for research.

[12] *Chem. Zeit.*, 1893, XVII, 982.
[13] "Der Erhartungsprozess der kalkhaltigen hydraulischen Bindemittel, Dresden, 1909.
[14] E. Stern, *Zeit. Anorg. Chem.*, 1909, LXIII, 160.
[15] H. Ambronn, *Tonind. Zeit.*, 1909, XXXIII, 270.
[16] R. J. Colony, *School Mines Quart.*, 1914, XXXVI, 1.
[17] *Ibid.*, also M. von Glasenapp, *Chem. Zeit.*, 1914, XXXVIII, 588.
[18] S. Keisermann, "Der Portlandzement, seine Hydrathildung und Konstitution," Dresden, 1910.
[19] *Zentr. Hydraul. Zemente*, 1911, II, 34.
[20] F. Blumenthal, "Dissert, Jena, 1912; *Silikat Zeit.*, 1914, II, 43.
[21] A. A. Klein and A. J. Phillips, U. S. Bureau Stand., *Technol. Paper* 43, 1914.
[22] P. H. Bates and A. A. Klein, *Ibid.*, 1916, No. 78.
[23] See also G. A. Rankin, *Jour. Franklin Inst.*, 1916, 747.
[24] P. P. von Weimarn, "Zur Lehre von den Zustanden der Materie," 2 vols., Dresden, 1914.

The Addition of Steel to Cast Iron

By J. E. Hurst

THE term semi-steel which is now applied to all those cast iron mixtures of which steel scrap in some form or other constitutes a part, is frequently widely misinterpreted. Strictly speaking, the true semi-steels are those iron-carbon alloys whose carbon contents are approximately midway between those of steel and those of cast iron. The addition of steel scrap to cupola mixtures does not bring about sufficient modification in the carbon contents; and a modification of the quantity of the other constituents, silicon, etc., does not justify the application of the term semi-steel. Indeed, malleable castings produced by the annealing of white irons according to the old English process are strictly the true semi-steels, and the alternative title of "steel mixture iron" is suggested for those cupola melted cast irons of which steel scrap constitutes a portion of the burden.

The use of steel scrap in pig iron mixtures melted in the cupola has now become extremely common in both cast and malleable cast iron foundry practice. Mixtures containing as much as 50 per cent of steel scrap along with pig or scrap cast iron are now frequently melted in the cupola for the production of high grade grey cast iron castings. Such additions form a very satisfactory means of reducing the silicon content, and by the same means a very substantial reduction in the phosphorus content can be brought about which is a consideration of the utmost importance, in view of the difficulties in obtaining hematite and other low phosphorus irons. The addition of scrap steel as a portion of blast-furnace burdens has been made with this same object in view.

The mechanism of the reduction of the melting point of steel in the cupola by the absorption of carbon from the coke and carbonaceous gases is now generally familiar. Broadly speaking, the amount of carbon absorbed by steel melted under cupola conditions is about 3 per cent, but there is every possibility of the amount varying between fairly wide limits about this percentage, the variations depending upon the conditions during melting. The factors involved in the absorption of carbon by steel during cupola melting are:

(1) The temperature attained in the cupola.

(2) The time of contact of the steel with the carbonaceous fuel and gases.

(3) The surface area per unit mass of steel, exposed to the direct action of the carburizing influences.

When these factors are fully considered, the possibility of fairly wide variations in the carbon content of the final product, and also the necessity for standardizing the conditions of melting, as far as possible in individual circumstances, will be readily apparent.

The following experiment[1] illustrates the absorption of the carbon by steel during melting in the cupola. A charge consisting of hematite and scrap cast iron, together with 20 per cent steel scrap, in the form of borings and plate punchings, was charged into the furnace in the following order: (1) Steel; (2) hematitie pig; (3) scrap iron. Almost immediately after the blast was turned on, a sample of the molten drops of metal was collected at the tuyere zone by means of a small clay crucible, attached to a suitably bent steel rod, introduced through one of the tuyeres. The analyses of the samples collected in this manner and of the final metal, are given in the table.

	Sample 1* Per cent	Sample 2* Per cent	Final metal Per cent
CC	2.50	2.94	0.86
Gr	—	—	3.07
Tot C	2.50	2.94	3.93
Si	1.21	1.59	1.63
Mn	—	—	0.48
S	—	—	0.085
P	0.73	0.74	0.66

*Samples 1 and 2 quenched. Carbon wholly combined.

[1] J. E. Hurst, "Proc." Brit. Fdrym'ns Assoc., 1915-16.

The rapid increase in the carbon content of the metal, and the fact that a large proportion of this absorption takes place after the metal has passed the tuyere zone and while lying among the bed coke in the hearth of the furnace, is shown by the analysis of the final metal tapped out into the ladle. This is an important consideration in the production of low total carbon content irons. The increase in the silicon and the curious behavior of the phosphorus in these samples are worthy of note, and amply illustrate the rapidity with which the whole of the charge melts.

The melting of steel scrap alone in the cupola with the resulting production of a high carbon content metal, paratively free from other elements, has apparently long been known, and frequently been used in the Bessemer steel practice. It is stated that the late Mr. L. F. Gjers, of the Gjers Mills Company, Middlesbrough, was probably the first to introduce this process.[2] Dr. Stead, in the correspondence on the report of the Malleable Cast Iron Committee of the Iron and Steel Institute, mentions the fact of having himself utilized this process years ago for the production of fluid iron for the purpose of recarburizing Bessemer blown metal.

The present author himself has independently carried out similar experiments with exactly similar results.[1] The product obtained by the direct melting of steel in this manner, as would be expected from its extremely low silicon contents and the conditions under which it is produced, is extremely "wild," and for the production of sound pigs must be suitably killed by silicon, manganese or aluminium additions. Dr. Stead states that the pigs produced by this method are decidedly "honeycombed." On this account, the direct melting of steel scrap with a calculated quantity of high silicon pig iron, as suggested by Dr. Stead for the production of pig iron for malleable purposes, is probably the better course to pursue. The practice is pursued by certain of the producers of so-called "refined pigs" for malleable-ising. Obviously the proportion of steel scrap per charge will depend entirely on the silicon content of the remaining portion, but there does not appear to be any doubt that the presence of 0.5 per cent silicon absolutely ensures the production of perfectly quiet metal and sound pigs.

The comparative ease with which steel borings in all but very finely divided forms can be melted in the cupola does not appear to be generally recognized. By using smaller charges both of metal and fuel, thus bringing about a more intimate mixture of fuel and material, and, incidentally, a more extended melting zone, steel in this form is very readily melted. This consideration is probably of great importance in ensuring a more extended and greater degree of preliminary carburization of the high layers of the charge. Extremely finely divided steel borings have a tendency to throttle the blast and promote scaffolding. Probably the greatest drawback to the use of steel borings is the difficulty of handling for charging purposes. This difficulty—on a large scale—could be easily surmounted by the use of open-top cupolas and electro-magnetic lifting appliances.

The absorption of sulphur during the process is frequently very large. It can to some extent be checked in the cupola by the addition of sand along with the limestone flux. It is suggested that the use of low grade manganese ores, which ought to be cheaply obtainable, would be of considerable advantage in the elimination of sulphur. With ordinary care, however, and the use of high grade coke, the extent of the sulphur absorption is of little moment in this process, if the metal is intended for the English malleable process.

The following results were obtained on melting steel borings and crop ends from the smithy in a cupola together with 10 per cent ferro-silicon. The final metal contained approximately .6 per cent of silicon and 3 per cent total carbon. The whole of this latter constituent is absorbed from the fuel in the cupola. Test bars were cast and annealed along with similar bars of hematite malleable pigs. The results obtained are given below:

Mixture number	(1)	(2)	(3)	Steel mix
Maximum stress	9.2 tons†	13.75 tons	18.0 tons	9.8 tons*
Maximum stress	22.0 tons	27 tons	25 tons	30 tons.
Elongation	3 per cent	3 per cent	3 per cent	3 per cent.
Bending angle	35 degrees	35 degrees	35 degrees	42 deg.

(1) Special hematite malleable pig.
(2) Special refined pig—probably made by melting steel scrap.
(3) Mixture containing malleable scrap.
*As cast condition. †Annealed condition.

In the present shortage of hematite malleable pig, the more extended official use of steel scrap, particularly steel borings and turnings, for the purpose of making malleable pigs would be of distinct national advantage. The use of scrap high silicon cast irons as used for the production of non-corrosive chemical ware is suggested as a possible cheap source of high silicon material necessary for the production of sound pigs.—*The Engineer.*

[1] *Foundry Trades Journal*, May 18th, page 270.
[2] *The Engineer*, November 27th, 1916.

The Limits of Complete Inflammability of Mixtures of Mine Gases and of Industrial Gases with Air

By George A. Burrell and Alfred W. Gauger

THE most important results of the inflammability experiments are shown in Fig. 1. The data are of importance in relation to the occurrence of inflammable gases in mines and to the industrial use of such gases. The gases investigated were gasoline vapor, ethane, methane, natural gas, acetylene, artificial illuminating gas, hydrogen, carbon monoxide, and blast-furnace gas. Vast quantities of gasoline vapor, natural gas, acetylene, artificial illuminating gas, blast-furnace gas, and hydrogen are being utilized for industrial purposes. Methane, hydrogen, and carbon monoxide are found in mines. Methane and ethane are constituents of natural gas.

Flame is said to be self-propagated through a mixture of combustible gas and air, or of combustible gas and oxygen, when enough of the combustible gas is present to permit combustion to spread through the mixture from any given point of ignition. Then propagation of flame takes place from layer to layer of the mixture without the continued presence of the source of heat that started the inflammation.

The conditions of experiment affect to some degree the limits of complete propagation. For instance, with mixtures of gasoline vapor and air, the low limitwas 1.5 per cent when a mixture of vapor and air was ignited from the bottom upward and 2.0 per cent when ignition was made from the top downward. With methane, the limit was 5.50 per cent for horizontal propagation of flame and about 5 per cent when ignition was made from the bottom upward. In coal mines, where methane is found, the limits for horizontal propagation are the most important. In general, the limits are slightly lower when ignition occurs from the bottom upward than when it occurs from the top downward.

In some of the experiments a glass vessel having a capacity of 2,800 c.c. was used as the container for the gases tested. Two copper wires entered through the sides and met at the center of the vessel. A current of 5 amperes at 15 volts was passed through the wires. Ignition of the gaseous mixtures was brought about by drawing the two wires apart while the electric current was flowing, thereby producing an electric flash.

In all of the author's experiments the explosion chamber was large enough so that its cold walls exerted no appreciable effect on the results. In spite of the slightly different results one can obtain under different conditions of experimenting, it is believed that the values for explosive limits given herein are close enough to be of decided commercial importance.

The results were obtained with gas mixtures kept at atmospheric pressure. The author found that with mixtures of methane and air and of gasoline vapor and air, raising the initial pressure to 6 atmospheres had no appreciable effect in changing the limits of complete inflammation, although the explosion, when it came, was of greater violence. As regards the effect of temperatures, raising the initial temperature from ordinary room temperature to as high as 200° C. only shifts the low limit for methane from 5.5 to about 5.05 per cent. Presumably increases of temperature and pressure affect to about the same degree the other gases mentioned in this report.

With a mixture of air and acetylene containing 2.81 per cent of acetylene, inflammation did not spread completely through the mixture. The flame traveled for 1 or 2 inches above the terminals but did not spread throughout the mixture. With 3.07 per cent of acetylene the flame spread entirely through the mixture.

With mixtures of hydrogen and air no propagation of flame could be noticed by the eye in mixtures containing 7 per cent of hydrogen when ignition was brought about by means of an electric spark from an induction coil driven by four small dry cells. But when the mixture was analyzed after sparking it was found that there had been a slight burning, undoubtedly only in the immediate neighborhood of the spark. As further experiments were tried with increasing percentages of hydrogen the amount of hydrogen that burned increased until, with 10 per cent hydrogen, it was completely burned.

With mixtures of methane and air, the limits for complete propagation of flame were found to be between 5.5 and 14.5 per cent. With 5.5 per cent of methane the explosion was not violent. The flame could easily be followed by the eye. With larger percentages of methane —or any other inflammable gas—the explosions became more violent. At the lower limit the flame travels very slowly compared with its speed in richer mixtures.

The incomplete burning of mixtures of air and of combustible gases in proportions below the low limit is well shown by the miner's safety lamp as used in testing for methane in mine air. When a safety lamp is placed in air containing about 1.5 or 2 per cent of methane, a small cap is usually seen on the flame when the latter is turned low. Careful and experienced men may detect as little as 1 per cent of methane with a modern safety lamp. As the percentage of methane increases, the cap grows higher.

Incomplete burning also takes place in mixtures of air and of combustible gases in proportions above the upper limit. The upper limit for complete propagation of flame in mixtures of methane and air is 14.5 per cent. But even with a proportion of methane as high as 20 per cent, an electric flash about one-half inch long causes a slight burning, the flame extending about 3 inches above the electric flash. The explosion chamber used was 6 inches wide and 12 inches high. The igniter was placed in the center.

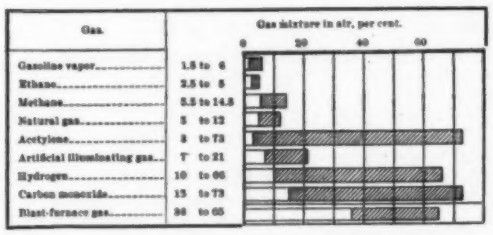


Fig. 1. Limits of complete inflammability of mixtures of combustible gases and air

At present oxygen is used in increasing quantities for industrial purposes, hence the limits of inflammability of mixtures of combustible gases with oxygen are of immediate interest.

As regards methane-oxygen mixtures it was found that the low limit was raised about 0.25 per cent when pure oxygen was used instead of air. The high limit was, however, extended from 14.5 to 45 per cent methane, the explanation being as follows: In a methane-air mixture containing 9.47 per cent of methane and 90.53 per cent of air there is enough oxygen for complete combustion of the methane to carbon dioxide and water vapor. But if more methane is present, carbon monoxide and hydrogen, products of incomplete combustion, result. This reaction takes oxygen that would otherwise form carbon dioxide and water vapor. Some heat is produced but much more heat is produced in the formation of carbon dioxide and water. As the percentage of methane

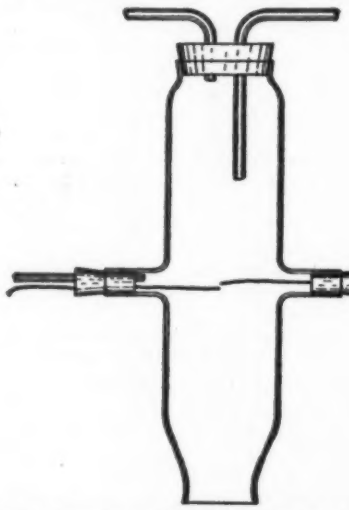


Fig. 2. Apparatus used in determining inflammability of mixtures of blast-furnace gas and air

is increased above 9.47 per cent, more and more carbon monoxide and hydrogen are formed from combustion until so much is formed that not enough heat is produced by ignition of the gas molecules adjacent to the igniter to cause the mixture to propagate flame. As air is only about one-fifth oxygen, substituting oxygen for an equal volume of air greatly increases the proportion of oxygen available for burning the combustible gas, the gas burns to water vapor and carbon dioxide, the heat of combustion is greater, and the upper limit of propagation becomes higher.

Presumably the upper limits for other gases would also be extended if oxygen were used instead of air. However, the low limits are the important ones as regards danger of accidental explosions, and these are seemingly not much affected.

The values for explosive limits given in this report refer to mixtures of the combustible gases with nearly pure air having a normal oxygen content. However, the oxygen content has to fall considerably before the limits of complete inflammability are appreciably changed. For instance, for mixtures of methane and air the low limit is given as 5.5 per cent of methane, which is the limit when the oxygen content varies between 17 and 21 per cent. With 17 per cent of oxygen in the mixture, the limit is raised to 5.7 per cent of methane. The oxygen content has to fall below 14 per cent to prevent all explosions in mixtures of methane and air. Replacing the nitrogen of the air with 20 per cent carbon dioxide raises the limit to 6.4 per cent methane. Raising the pressure of a gas mixture above atmospheric has no appreciable effect in changing the explosive range.

The authors' compressed mixtures of hydrogen and oxygen in a steel bomb to 100 atmospheres before ignition and found that the explosive range was only a trifle different than the range at atmospheric pressure. The low limit was raised about 1 per cent.

Explosions have occurred at blast furnaces owing to the leakage of air into gas conduits and the subsequent ignition of the resulting mixture. The results of experiments to determine the explosive limits of mixtures of blast-furnace gas and air are presented below.

In the experiments a glass vessel of the shape shown in Fig. 2 was used. It was 8½ inches long and had a capacity of 900 c. c. A little above the center two copper electrodes were so arranged that they could be separated by the operator to produce an arc. The top was capped with heavy waxed paper. All experiments were made with the mixtures saturated with water vapor at room temperature and atmospheric pressure.

The blast-furnace gas used had the following composition:

Constituent	Per cent
Carbon dioxide	10.0
Oxygen	0.5
Hydrogen	2.7
Carbon monoxide	27.5
Methane	0.3
Nitrogen	59.0
	100.0

The proportions of blast-furnace gas that mark the limits of inflammability of mixtures of air and blast-furnace gas of the composition given are 44.9 to 45.7 per cent for the low limit gas and 64.5 to 65 per cent for the high limit. Thus, in order to have an explosion of blast-furnace gas, not less than 35 cubic feet nor more than 55 cubic feet of air must be present in 100 cubic feet of a mixture of such gas with air.

*From Technical Paper No. 150 issued by the Bureau of Mines, Dept. of Interior.

Use of "Couverture" in Antimony Smelting

AT the recent meeting of the American Institute of Mining Engineers, Chung Yu Wang, in speaking on antimony smelting in Japan, called attention to the well known fact that the "market always demands good stars with fern-like structure on the slab of regulus before its acceptance. The appearance of such structure does not actually indicate the relative purity of the regulus, but is only the result of cooling it under the cover of a properly prepared starring mixture—in the absence of a proper English term, I shall call it by its French equivalent *couverture*—whose fusion point is lower than that of antimony, which is 630 degrees C. Of course, when the regulus contains impurities like sulphur, arsenic, lead or iron to any appreciable quantity, its surface shows it by specks, by a leaden appearance or by an ill-defined appearance of the fern-like structure. On the other hand, I have seen many a slab of regulus, with impurities above what are considered to be the limits imposed by buyers, whose stars are still bright and well-defined with all the appearance of well refined regulus. Now since the buyer demands such unnecessary adornment of the regulus, he has to pay for it; for the costs for starring 1 ton of regulus amount to from $10 to $60 (Mexican), according to the market price of the antimony compound used. The proper procedure for charging any of the above mixtures is as follows: The mixed couverture compounds (usually antimony tioxate plus soda or potash), are immediately charged into the reduction furnace as soon as the skimming is finished. The doors are closed and vigorous firing is maintained; as soon as it is observed that the mixture is completely melted, ladling commences. Each ladle dips into the molten metal and, in coming out, picks up a certain quantity of the molten couverture, which, when poured out rapidly together with the metal into a hot mold, completely covers the metal on all sides." The thickness of the solidified couverture varies from 1 to 2 mm. on all sides, 5 to 7 mm. on top, and varies from ⅛ to ¼ the weight of the regulus produced. About ⅓ of the compound is lost by volatilization and by wall-fluxing; it is hammered from the slab and re-used until it becomes foul, when it is resmelted. —*From a report in Chem. and Met. Engineering.*

Anomalies in the Animal World—Part XIII

Fishes of the Most Remarkable Kinds Known to Naturalists

By Dr. R. W. Shufeldt

FISHES constitute such an immense group of animals in the world's fauna, and such fossil fishes—and there are a large number of them—as have come into the hands of science, indicate not only that they represent an assemblage of vertebrates of great antiquity, but that thousands upon thousands of most interesting species have, ages ago, become utterly extinct. All of which being true, it must be evident that but scant justice could be done in a single brief chapter, as is presented in the preceding one, to account for some of the anomalies of their special senses.

Where some of these special senses of fishes are anomalous, the fact renders the species presenting them likewise anomalous, and, everything else being equal, to the full extent to which the anomaly departs from what is normal in ordinary fishes. This is a subject to be pursued further in the present part, and it may be remarked at the outstart that, notwithstanding the fact that flat-fish, flounders, soles, plaice, and their numerous allies, although known to everybody, stand among the most curious fishes we can have any knowledge of.

There are a great many species of them, and if we select an average flounder or a plaice to stand for them all, it will be remembered that they are *flat* fishes, with both eyes upon one side of the head (Fig. 1); dark colored on their upper sides—where they are generally spotted—and very light-colored, or even white, below. Their fins practically encircle their entire body; and when one swims, it swims by virtue of an undulating action of the entire fish from head to tail—a most beautiful locomotion which can be well studied when flounders are kept in aquaria.

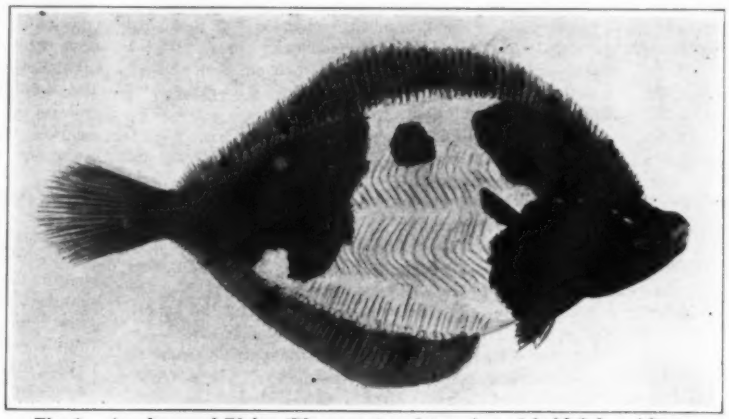


Fig. 1. An abnormal Plaice (Pleuronectes platessa), a piebald fish. After a colored drawing from life by Miss Anne Willis

Practically, they live entirely on the bottom, where the colors of their upper surfaces so closely resembles the soft mud upon which they habitually rest that they are seen only with difficulty. Moreover, when swimming, and a flounder or "mud-dab" desires to come to a stop, it has a way of convulsively agitating its fins—an action that causes the fish to settle down into the mud or sand a ways, thus rendering it still less visible to its enemies.

One of the most peculiar things about flounders is that the very young of any of the species swim *upright*, as in the case of adults of all ordinary fish. Not only this, but the *eyes* of young flounders are likewise as in ordinary fish—that is, one on either side of the head, and not both on the same side. This change comes about gradually, as the fish grows, and in some very rare instances it is sometimes arrested. When this happens, the eye may get only part of the way around to what subsequently becomes the upper side of the head. It may be checked in its advance at the margin of the head, opposite the gill opening, and *remain there* throughout life! A case of this kind, and a beautiful specimen of it, was, many years ago, brought up before the Biological Society of Washington, and, being present, the interest it created is now very well remembered by me.

Experimental ichthyologists often wondered whether—in the event of flounders and plaice being kept in captivity in such a way that the light would reach, at all times, *both* sides of the fish or *only* the under side—such a specimen would show any changes in its coloration. Some ten years ago, Mr. J. T. Cunningham, F. Z. S., made, at the Plymouth Laboratory, England, some very important experiments with respect to this question. In his able report he says that, in the case of plaice (and flounders, of course), "the whiteness of the lower side is due to the absence of black and colored pigments and the presence of a white substance in the skin. Specimens of plaice and other flat-fish are, however, occasionally obtained which show more or less color on the lower side, varying from small patches to complete pigmentation of the whole surface. Conversely, specimens also occur in which pigment is entirely absent from part of all of the upper side, the lower side being white as usual. The colorless area in such specimens is usually sharply defined, and there is no gradual transition from the colored region to the uncolored." (See Fig. 1.)

It will not be practicable to quote in full Mr. Cunningham's somewhat length report in this chapter, though it will be as well to reproduce a few of his conclusions, which are both interesting and important.

"The occurrence in nature," he says, "of pigmentation on the lower side of a flat-fish is often regarded as an instance of reversion. The ancestral flat-fish was doubtless equally colored on both sides, like an upright fish such as the John Dory, and when the flat-fish is equally colored on both sides, or partially colored on the lower side, it is natural to conclude that it has reverted more or less completely to the ancestral conditions. But on the other hand, when the upper side is pratically white, this cannot be due to reversion, for it is impossible that both of the variations in opposite directions can resemble the ancestral fish.

"Therefore it is by no means certain that the occurrence of pigment on the lower side is due to reversion, and in fact both kinds of variation may be regarded simply as variations in opposite directions.

"Now these variations in both cases are variations of an asymmetrical animal toward symmetry—that is to say, either side may, in individual cases, more or less completely imitate the other, instead of differing from it. Such variations are known to occur in all animals in which the two sides are normally different. From this point of view, the white patch on the upper side of our piebald plaice may be regarded as imitating the lower. Then, if the lower side is white in consequence of absence of light, the white patch will imitate it although itself exposed to light. So also may be explained the fact that, when pigment is present on a part of the lower side, it persists in spite of the fact that there is no light to affect it. It is there because part of the lower side imitating the upper, is developing in the same direction is as the upper, instead of in its own proper direction."

Other experiments convinced this naturalist that the "variations themselves, whether consisting in the presence of pigment on the lower side or the absence of pigment on the upper, are not due to special conditions, but are spontaneous. But when white occurs on the upper side it is not a case of albinism, like the white in a piebald horse or mouse, but is connected with and dependent upon the absence of pigment on the lower side; and when the lower side is exposed to light, pigment appears both on that side and in the white area on the upper side."

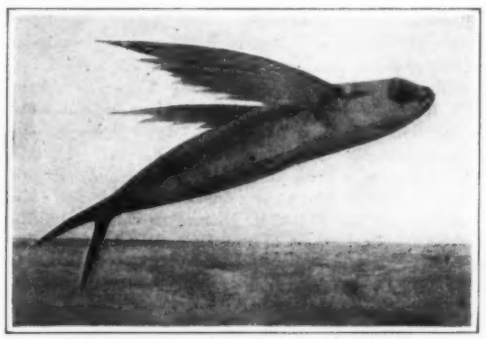


Fig. 2. A flying fish, after W. Saville-Kent

These experiments of Mr. Cunningham's will bear further amplification.

There are known some peculiar little parasitic fishes called "Tierasfers" which are worthy of notice in the present connection. They are semi-transparent, eel-like creatures that find their way into the mantle-cavities or even the bodies of jelly-fish, big clams, and other molluscs, sea-cucumbers, etc. Here they give considerable annoyance to their host; and especially is this true in the case of the big pearl oysters of the tropics, which, when one of these piscine parasites dies within its cavities anywhere, and the discomforted mollusc cannot rid itself of it, it proceeds to seal it up hermetically with a layer of its pearly secretion.

There is another group of small, red-and-white banded, semi-parasitic fish found in the Australian seas that are curious from the fact that they spend some of their time among the crowded tentacles of a Giant Sea Anemone. When away from their host they are sometimes pursued by larger fish as legitimate prey. When this occurs these beautiful little *Amphiprions*, as they are called, rush back to the protection of the big Anemone, followed by their would-be devourer, who unexpectedly, in his eagerness to capture his quarry, suddenly finds himself among the stinging tentacles of the host, and he not only misses the *Amphiprion*, but is careful not to chase one again.

Thus, to a greater or less extent, is this little semi-parasitic fish protected.

Some fish can spring from their natural element, and enjoy flights of various distances in the air. Two principal groups of these are known, and in both the "flights" are rendered possible through the enormous development of the pectoral or breast fins. Probably the least known of these fishes are the flying-gurnards, one species of which is abundant in the Mediterranean Sea. These Flying-gurnards must not be confused with the true Flying-fish, which belongs to an entirely different family, closely related to the herrings. (Fig. 2.)

Flying-fish never flap their pectoral fins in their sailing flights; and they are not true "wings," but act only as a parachute, a matter already discussed in previous chapters of these papers when touching upon flying animals generally, as bats, frogs, etc.

These finny fliers of the deep, when they dart from the water to escape capture on the part of some form preying upon them, guided by some peculiar instinct, always go with the wind. Over the first third of their course, their rate of going may equal at least ten miles an hour, but after that it gradually diminishes. Sometimes this flight, as has been noticed by me in the South Atlantic and the West Indian seas, as well as in the Gulf of Mexico, is on the arc of a beautiful curve, whatever the cause may be which allows of their executing it out of water. It would be of benefit to the fish, however, in one way at least, that of baffling the species in pursuit, as the latter would naturally keep straight ahead on its course, assuming that the flying-fish would travel out of water in a straight line. Some of these flights have covered a distance of no less than five hundred feet; but the flier, once under way, *cannot change its course*, except when it is enabled to do so by touching the water with its tail, thus altering its direction.

Flying-fish keep away from ships if possible, but they cannot well help themselves at night when their sight is poor. At this time, as Dr. Gunther of the British Museum points out, "they frequently fly against the weather-board, where they are caught by the current of air and carried upward to a height of 20 feet above the surface of the water, while under ordinary circumstances they keep close to it." At these times they sometimes strike the rigging somewhere, and fall on the deck of the vessel, where, upon one or two occasions, they have been found and examined by me. One of these was over a foot long; a California species may attain a length of 17 inches (*E. californiensis*). About nine species of this family (*Exocœtidæ*) are known to science.

There are true fishes that breathe with true lungs, which organs in them supplant almost entirely the gills; and these are fishes, like the Australian Lung-fish, that connect the Pisces and Amphibia. These fish inhabit the muddy rivers of Queensland, and are much esteemed for food. A large one will measure 6 feet in length and weigh as much as 20 pounds. They are frequently obliged to rise to the surface to take in air, or else they would drown in very short time.

We have in this country, in the South, a sort of lung-fish, about which much has been written.[1] Africa and

[1] Shufeldt, R. W., "The Osteology of *Amia calva*, including certain special references to the skeleton of Teleosteans. Gov. Printing Office, 1885, pp. 1-132, pls. 1-14. This curious fish was found by me to be very abundant in the lagoons about the city of New Orleans, La.

South America also have curious, eel-like lung-fishes in their faunæ, the first being known as the Mud-fish, the latter as the Lepidosiren, both being animals possessing very extraordinary habits.

But fish furnish more anomalous and extraordinary species than all the rest of the known vertebrata put together *twice over!* And were we to briefly describe even the most distinctly remarkable ones, this chapter would never be ended. In such a list we would find, among many others, the curious Bottle-nosed Chimæra, with its peculiar tactile organ sticking out in front of its mouth, a fish that lays an egg that mimics a piece of seaweed. Then there are the bizarre shaped Weaver-fishes, the Sea-scorpions, and the Stone-fishes. And as for the several species of Sword-fishes, their natural history is so interesting that entire reports have been devoted to them alone. One of these fishes attains a length of 15 feet, and its performances are sometimes most incredible.

Frank Buckland says that there is, in the Royal College of Surgeons of England, a portion of the bow of a whaling-ship, into which a big Sword-fish had thrust its "sword." "At one single blow," says this well-known naturalist, "the fish had plunged his sword through, and completely transfixed 13½ inches of solid timber. The sword had of course broken off and prevented a dangerous leak in the ship."

Many have heard of the Remora or Sucking-fish, which, by the powerful "sucker" on the top of its head, can fasten itself to the bottoms of ships, or to big sea animals of any kind. This "sucker," by the way, is a modified dorsal ray of the back-fin or dorsal-fin—a most interesting fact which Doctor Gill pointed out to me many years ago.

Remarkable indeed are the many species of Angler-fishes, both great and small, placed in several different families: the Sticklebacks which build nests, which we sometimes see in aquaria; the Garpikes and Pipe-fishes, and all their interesting congeners. There is not even sufficient space here to mention these by name.

In a previous chapter, several of the armored fishes were referred too, and, brief as those accounts are, they must answer for a notice of these strange forms.

We cannot so easily dispose of the Sea-horses, however, for they stand among the most eccentrically formed of all. These small and curious creatures, of which there are numerous species in various parts of the world, have been so lavishly illustrated in both popular and technical literature, that almost anyone with any interest in fish will recall their general form. They are frequently seen in aquaria, where their stocky little bodies, and downwardly flexed heads—in a way reminding one of the head of a conventional horse—and tails curled forward, chameleon fashion, immediately command one's attention. As they move about in the water by the aid of their delicate little dorsal fins, they often seize the stems of the plants in their neighborhood with their coiled tails, which, by the way, lack a terminal fin and are prehensile, and for this last reason totally unlike the tail of any other known species of fish.

Everything about a sea-horse tends to render it more or less inconspicuous, and, on that account, very likely to escape notice. Indeed, their swaying motion, when floating gracefully among the delicate seaweeds where they are found, still further shields them from observation; and the fact that, when swimming, their bodies are more or less vertical causes them to attract even less attention. But for a fuller description of these strange little denizens of the ocean, the reader should consult my previous writings about them.[2]

Before introducing the next group of fishes it will be necessary to say a word about ancient and long ago extinct forms, in that we may account for the peculiarities of their now existing descendants.

The Coal Measures required between one million and a million and a half years to form, at a conservative estimate. It has been carefully estimated that, from the present time to include the Basal Eocene, 3,000,000 years were required. Between the Basal Eocene and the Coal Measures of the Carboniferous Age the three great ages of the Mesozoic Era, requiring a very much longer period of time, were formed. Following the Caboniferous Age is the Devonian Age, and how old that may be the reader may imagine.[3] It is safe to say at least ten millions of years—maybe more or maybe less. However, LeConte says: "The grand characteristic of the Devonian age is the *appearance* and *culmination* of the class of fishes. This is a great step in advance; for we have here the introduction, not only of a new class, but a new department (Vertebrata), and the highest of the animal kingdom. These earliest fishes, as might be expected, however, were far different from typical fishes of the present day. They belonged wholly to the two orders *Ganoids* (gar-fish, sturgeons, and mud-fishes) and *Placoids* (sharks, skates and rays), and to families of these orders which are now either wholly or nearly extinct." (*loc. cit.* pp. 334, 335).

One of the chief characters of these now long extinct fishes was the remarkable and impenetrable armor which their scales formed. This was particularly the case with the *Ganoids*, in which group the scales were *enameled*, thick and bony. Often they were intricate and of a rhomboidal outline; again, in some species they were in *oblique* rows, making beautiful joints at their margins. Some species had only the head covered with such plate-like scales; in others the head and body, and, finally, in still others the entire body. They all had cartilaginous skeletons—both *ganoids* and *placoids*. Some of their characters were distinctly *reptilian*, and others *embryonic*, and, as the specimens, owing to their beautiful enameled coat-of-scales, are generally preserved as fossils of an elegant kind, they have been studied with unusual care and interest, an enormous literature describing them having naturally followed.

These introductory notes on these extinct fishes are made here in that the nearest *living allies* of the Devonian fishes may be referred to; for the limitation of space will but admit of a brief reference in the case of any of them. They all present more or fewer characters of their ancient ancestors, especially in the matter of their scales, as above described; their rudimentary lungs; the nature of their fins, and their general morphology.

Chief among these existing species we find the American mud-fish (*Amia calva*) already referred to above; the living cestraceout (*Cestracion phillippi*), an Australian shark-like species; our common garpikes (*Lepidisteus*); the *Ceratodus*, already noted above; the South American *Lepidosiren*; the *bichir*, which is found in the Nile and other tropical rivers of Africa, and the Reed-fish of Old Calabar, an eel-like species allied to it.

The Bichir of the Nile is an elongate fish that may attain a length of some four feet; it may be recognized on sight by the peculiar structure and arrangement of its back and dorsal fin. This is divided up into some ten to eighteen small fins that are detached from each other. Although the Bichir possesses gills, they are supplemented by a respiratory apparatus of unusual interest to the comparative anatomist. Young Bichirs breathe after the manner of a tadpole, that is by means of the large external gills which are post-cepahlic.

Our big Alligator gars of the South, and the various species of Sturgeons, are both allies of the Devonian extinct fishes. The former possess a superb armor composed of dense, quadrangular scales coated with enamel. A big alligator gar is nearly as dangerous as a shark and very difficult to kill. My experiences with them, many years ago in Louisiana, were quite noteworthy. They occasionally attain a length of six feet.

There are among existing fishes a great variety of species of Sharks and Rays. Relatives of the sharks are the well known Dog-fishes that have almost a cosmopolitan distribution. Among the numerous species of them we find the Nurse and Rough Hound, which are, as my friend, F. G. Aflalo says: "Spotted leopards of the sea, and the latter has a very curious property. If a fresh-caught 'row-hound,' as the fishermen pronounce the name, be put in a basket or boat's well with pollack and other fishes, the points of contact will be marked by discoloration of its neighbors. This is probably due to some acid and bleaching secretion of the row-hound's skin, for which some economic use might possibly be found."

Most all sharks are dangerous, especially so the Basking shark, the White shark, the Blue shark, the Dusky and the Ground shark, and the Hammer-head shark.

This last occurs on both sides of the Atlantic, though it is far more common in the tropical waters of the South Seas of this country. It has been seen by me several times in the harbor of Key West, Fla., and on the coast of Hayti. It may reach 25 feet in length, and one of them taken many years ago off the coast of Long Island had part of the body of a man and his clothing in his stomach.

The Saw fish (*Pristis*) is a unique form, with its great, bony beak, often six feet in length, and having powerful, sharp teeth inserted all the way round its free margin. This weapon is a very powerful as well as dangerous one, as many will attest who have had experiences with this fish.

Among the numerous species of Rays or Skates, allies of the Sharks, we have the extraordinary Torpedo or Electric Ray, which may come to weigh as much as 200 pounds. It has an electric organ located between the head and gills and pectoral fins. With this the fish can given an electric shock severe enough to knock a man down.

Only once in my life has the opportunity been afforded me to see that enormous ray known as the Sea Devil or Ocean Vampire. The specimen was upward of twenty feet long and nearly as wide, and must have weighed several tons. It was in Key West harbor, where it came up alongside of an anchored tugboat of above usual size, and, seizing her cable, it dragged the steamer from its moorings for a mile or more before the musket-fire it received from the crew compelled it to loose its hold and disappear.

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[2] Shufeldt, R. W., "Chapters on the Natural History of the United States," New York, 1897. Chap. VI., "Sea-horses and Eels." Fully illustrated and contains an account of their breeding habits.

[3] Leconte, Joseph, "Elements of Geology," New York, 1883. "There are many facts connected with geology, especially the fact of evolution, which cannot be understood without the admission of inconceivable lapse of time. For this reason it is important that the mind should become familiarized with this idea. It will not be out of place, therefore, to make a rough estimate of time based upon the amount of erosion.

"We have already seen that, taking the Mississippi as an average river in erosive power (it is probably much more than an average), the rate of continental erosion is *now* about one foot in 5,000 years. At this rate, to remove an average thickness of 6,000 feet would require 30,000,000 years."

Here is still another and *independent* estimate based on erosion, one made by the eminent scientist, Alfred Russel Wallace." Taking the whole land-surface (erosion-area) at 57,000,000 square miles, and the sedimentation area as thirty miles wide along a coast-line of 1,000,000 miles (=3,000,000 square miles), then with an erosion-rate of one foot in 3,000 years instead of 5,000 years, the sedimentation rate would be nineteen feet in the same time, or one foot in 157 years. But the extreme thickness of strata is at least 177,000 feet. This would take 28,000,000 years." ("Island Life," p. 210). If we take the average of these two estimates we have 29,000,000 years as required for the accomplishmet of continental erosion, and "still beyond this", says LeConte, "beyond the *recorded* history, is the infinite unknown abyss of the *unrecorded*. The domain of the Geology is nothing less than (to us) inconceivable or infinite time" (*loc. cit.*), p. 276.

Poisons and Drugs of Animal Origin*

By George Barger

THE protective posions which occur in many groups of animals have mostly not been isolated in a state of chemical purity. Generally, however, we have at least some conception of their chemical nature. Thus cobra-venom contains a nerve-poison, which paralyses the respiratory center, and also a haemolytic principle. The former, ophiotoxin, has, according to Faust,[1] a composition corresponding approximately to the formula $C_{17}H_{28}O_{10}$ and resembles the saponins in physical properties; anyhow it seems to be nitrogen-free. The haemolytic substance is, according to Manwaring,[2] a lecithinase, an enztyme which splits off one of the fatty acid groups of the lecithin contained in the victim's blood, and this partially hydrolysed lecithin is known to be haemolytic. Previously Kyes[3] had imagined that when snake-venom is shaken with a lecithin solution, a compound soluble in chloroform is formed, in which one of the fatty acid groups of lecithin is replaced by an active constituent of snake-venom, to form a so-called lecithide.

The active principle of a toad has, on the other hand, been obtained crystalline and quite pure. A few years ago Abel and Macht[4] isolated from the so-called parotid skin gland of the large central American toad, *Bufo agua*, a substance which undoubtedly has the composition $C_{18}H_{24}O_4$; it has a very powerful digitalis-like action on the heart and is also a diuretic. These authors have thus found a scientific basis for the former great reputation of powdered toad skins as a cure for dropsy. Their use for this purpose now only survives in China under the name of "senso," a drug which Shimizu[5] has lately shown also to contain bufagin. The parotid secretion of *Bufo agua* is further remarkable in containing over 5 per cent of epinephrine (adrenaline) identical in every respect with that obtained from the suprarenal gland of the higher animals.

Whilst bufagin of the toad, and apparently also ophiotoxin of the cobra, are neutral non-nitrogenous substances, the skin of the newt, *Salamandra maculosa*, contains two alkaloids, which Faust[6] has isolated as crystalline sulphates. They are samandarine, $C_{20}H_{40}ON_2$ and samandaridine, $C_{22}H_{31}ON$; both are powerful nerve poisons. From the latter base Faust claims to have obtained isoquinoline by distillation with zinc dust.

The difficulty of obtaining enough material is often a great hindrance in chemical work on animal poisons and is illustrated by Langer's[7] investigation of the posion of bees. This author collected 25,000 bee stings; but since the drop of poison ejected from a sting weighs only 0.2—0.3 mgrm. and consists mostly of water, only a few grams of the crude poison was obtained. The active principle in this case gives strong precipitates with alkaloidal reagents, but does not appear to be a protein.

More important than the protective poisons of the lower animals, of which a few examples have been given above, are the products of the so-called ductless or endocrine glands. These internal secretions, called by Starling hormones ("chemical messengers"), have been studied, especially in the larger mammals, including man, and some of them have of late years come into prominence as very potent and specific drugs. The remedial administration of the whole gland or of an extract has

*From the *Journal of the Society of Chemical Industry*.

given rise to the name organotherapy. So far the preparation of the pure active principle on an industrial scale has only been accomplished in the case of the suprarenal gland. Two years after the isolation of adrenaline by Takamine[8] in 1901, its synthesis was patented by Meister, Lucius, and Bruning (Ger. Pats. 152,814 and 157,300). Chloraceto-catechol is combined with methylamine and the ketone is then reduced to thesecondary alcohol. Since, owing to the slight physiological activity of *d*-adrenaline, the synthetic racemic substance was found to have not much more than half the activity of the natural *l*-variety, the Hochst firm had the enterprise to effect a resolution on the industrial scale by means of the bitartrates (Ger. Pat. 222,451). The dextro-enantiomorph is not allowed to become a waste product, but is again recemized by heating with dilute acids (Ger. Pat. 220,355). Several other syntheses have been patented, chiefly by the same firm, but they do not appear to be of practical value (Ger. Pats. 155,632, 185,598, 189,483, 193,634, 195,814, 209,609, 209,610, 209,962, 212,206, and 216,640), nor have the closely related substances arterenol, homorenon, and epinine found a wide application as substitutes for adrenaline, although their physiological activity is in most respects qualitatively similar. The synthesis, involving a stereochemical resolution, may appear complicated, but it should be remembered that a pair of bullock's suprarenals together contain only 30—40 mgrms. of adrenaline, or about 0.2 per cent (in marked contrast to the 5—6 per cent contained in the parotid secretion of *Bufo agua*, referred to above). On the other hand the drug is extremely active and it is said that by some physiological reactions as little as 0.000002 mgrm. may be detected.

A second important ductless gland is the thyroid. Its oral administration, introduced in 1891 by Murray, appears to be a complete remedy in those diseases where the natural secretion is defective (myxœdema, cretinism) and constitutes the greatest triumph of organotherapy. The chemical constitution of the active principle has not been established until quite recently. Baumann,[9] who more than 20 years ago discovered the iodine content of the thyroid, obtained from it by boiling with dilute sulphuric acid an amorphous impure substance iodothyrin, with 9—10 per cent of iodine. The statements as to the physiological activity of this substance are conflicting. The same may be said of a protein, thyroglobulin, obtained by Oswald.[10] Recently Kendall[11] has employed alkaline hydrolysis, with greater success, and a paper has been announced entitled, "The isolation and identification of the iodine-containing compound which occurs in the thyroid" (J. Ind. Eng. Chem., Oct., 1917, p. 985). Previous papers by the same author[11] have indicated that the free base contains 65 per cent of iodine, its sulphate 60 per cent. The molecular weight of the base is about 586. A photomicrograph of the crystals has also been published. The base is active in cretinism in very small amounts and the limit of tolerance is 2 mgrms. daily. The substance seems to be an indole or tryptophane derivative, and this would explain previous statements in the literature that iodized blood proteins have a physiological action like that of the thyroid gland.

If the constitution of the thyroid active principle has been definitely established, its industrial syntheses will be an important problem. By the use of a synthetic preparation the difficulties of dosage might be overcome, which at present result from the variability of the gland in animals. The standardization of thyroid preparations has so far only been carried out by physiological means; their iodine content does not afford a sufficient indication of activity.

Reid Hunt[13] has devised a peculiar and very sensitive method for recognizing the activity of thyroid preparations; he finds that very small quantities of the active gland increase the resistance of mice to the toxic effect of acetonitrile; as little as 0.1 mgrm. of the gland may double their resistance to this poison. By this means Hunt claims to have proved the presence of the thyroid secretion in the blood of sufferers from Graves' (Basedow's) disease, which is generally regarded as due to an excessive functioning of the gland. A more recent and probably simpler method of testing, which illustrates the effect of the active principle on metabolism, is due to Gudernatch[12] and consists in feeding the thyroid preparation to tadpoles. The latter diminish in size, the tail becomes absorbed, and at the same time development is accelerated, so that rudiments of the legs appear earlier than in the controls. This method has even been recommended for the standardization of commercial preparations. (Photographs, illustrating it, will be found, for instance, in a paper by Rogoff and Marine, J. Pharmac. exp. Therap., 1906, 9, 57). By means of the tadpole method Marine and Rogoff[14] have shown that when potassium iodide is injected intravenously into an animal with a defective (iodine-free) thyroid, the iodine is fixed by the gland almost immediately, but it takes about 16 hours before this iodine is converted into the physiologically active substance.

On account of its widespread occurrence we may here briefly mention goitre ("Derbyshire neck"), the commonest disease of the thyroid, although it is not connected with a defective secretion of the active principle. The dispute as to the cause of this disease has lately been settled by McCarrison, who attributes it to an infection by an organism from the soil and from drinking water, thus explaining its endemic occurrence in many parts of the globe, while in other regions it is rare or absent. Closely associated with the thyroid gland and often embedded in it are the parathyroids, small organs, which seem to be even more important to life than the thyroid itself. Nothing is known about their active principle. After removal of the parathyroids the urine contains considerable quantities of methylguanidine (Koch[15]).

The pituitary (hypophysis cerebri) is another very important ductless gland. It consists of an anterior nervous, and a posterior infundibular portion. Its situation under the brain makes its experimental extirpation difficult, and attempts in this direction have not thrown much light on the functions of the parts. One of these functions is an influence on growth; the rare disease acromegaly, characterized by an enlargement of some bones (of the lower jaw, hands, feet, etc.), is associated with lesions of the pituitary. Brailsford Robertson[16] has recently extracted a substance from the anterior lobe, for which he claims that it has a definite effect on the growth of mice, making them heavier and sturdier, although not larger, than the controls. This substance, tethelin, is a phosphatide with nitrogen and phosphorus in the ratio 4N:P, but probably not pure.

More than the anterior, the posterior portion of the pituitary has attracted the attention of physiologists. Its extracts have a pronounced action on the blood pressure, on the isolated uterus, on the kidney, on the mammary gland, etc. The pressor action of the pituitary was discovered by Oliver and Schafer[17] almost simultaneously with that of suprarenal extracts. The rise of blood-pressure is smaller, but more persistent than that due to adrenaline. Whether the diuretic action, discovered later, is due to the same or to a different hormone is not known, and the same may be said of the powerful action of infundibular extracts on the uterus, which was discovered by Dale[18] and has of late been applied therapeutically with great success. Various indications, however, point to there being several active principles. Unfortunately no active substance has been isolated in a state of undoubted purity. Most is known about the properties of the pressor substance; it can be boiled in neutral or slightly acid solution without much loss of activity, but is rapidly destroyed by alkalis. It is also destroyed by trypsin, whence it would seem to be a peptide. It is insoluble in absolute alcohol and other organic solvents and is readily absorbed by charcoal and by precipitates formed in its solutions and thus it is carried down by phosphotungistic acid. The action of pituitary extracts on the uterus, resembling that of the ergot substance β-iminazolylethylamine, and the fact that pituitary extracts, like this glyoxaline, give a diazo-reaction, has led to speculations concerning a similarity in the constitution of the two substances. Guggenheim[19] condensed β-iminazolylethylamine with various amino-acids, forming dipeptide-like substance which, however, only had a slight activity. Some years ago Fuhner[20] stated that Meister, Lucius, and Bruning had obtained by means of phosphotungstic acid four crystalline sulphates, all physiologically active (compare Ger. Pat. 268,841). Various others have claimed to have isolated an active principle, *e. g.*, Baudouin[21] and Bouin and Ancel,[22] but none of these claims seems to be well founded. It is possible that all the four Hocht bases were contaminated with a highly active substance; it is at least significant that these bases have not been characterized chemically. The isolation and the determination of the constitution of the pituitary active principle is evidently a matter of great difficulty, but would undoubtedly be of great value, particularly if it were followed by synthetical manufacture.

In reviewing drugs of animal origin we must finally draw attention to the immune sera, the production of which forms a peculiar and highly specialized branch of chemical industry. Of these anti-diphtheritic and anti-tetanic serum are by far the most important, the former in times of peace, the latter during the present war. They are obtained by injecting the filtrate from cultures of bacilli into horses. The soluble toxin renders the horses immune and their blood is subsequently found to contain so-called anti-toxin, sufficient to neutralize large quantities of the toxin. By periodic bleeding and separation of the serum, a highly specific and very valuable remedy is obtained. The anti-toxins, like the toxins, are unstable and very complex substances; their isolation seems to lie quite beyond the present bounds of chemical knowledge.

The high hopes raised at first by the success of diphtheria anti-toxin have not been wholly fulfilled, as regards the treatment of other bacterial diseases. In most cases the organism does not secrete a soluble poison into the culture medium, and hence weakened or killed cultures are injected. Then a so-called bacteriolytic serum may result, *e. g.*, with cholera cultures a serum dissolving cholera vibrios. Among bactericidal sera, obtained in a similar way, we may mention those against streptococci, pneumococci, typhoid, and cholera, which are still more or less in an experimental stage; perhaps the anti-meningococcus serum is of most importance in this group. In a few cases immune sera have been employed successfully against non-bacterial toxins. The anti-venin of Clamette is an efficient protection against snake bite, but the difficulty here is that the immune serum against one species of snake does not protect against the bite of another species. A further interesting non-bacterial anti-serum is that from animal immunized against pollen grain.; it is used to combat hay-fever.

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Concentration of Sulphuric Acid

THE concentration of dilute sulphuric acid, as usually carried out by means of hot flue gases passed in countercurrent over the acid in a series of volvic stone vessels has the disadvantage of causing considerable loss of acid in the vapors. This is due to the comminution of the acid and the formation, under the action of the hot blast, of a considerable amount of anhydride from the concentrated acid, which is only condensed with difficulty in water or weak acid. The authors therefore propose to reverse the usual process and pass the acid in a shallow undisturbed stream, through a series of twelve vessels of special design, in the same direction as the flue gases. Each vessel is in the form of a rectangular box, 1 meter long, 1.5 m. wide, and 0.5 m. high, provided with circular inlet and outlet, the latter at a lower level than the former, and keyed together. Sodium silicate is used to make the joints tight, and the whole is covered with sheet lead 10 mm. thick. The acid to be concentrated is introduced into the first vessel through a pipe in the side. Every alternate vessel is provided with a pipe through which any desired proportion of vapor may be led away for condensation. Gases at 1,200° C. can be employed directly on acid of 53° B., and the proportions should be adjusted so that (a) the concentrated acid is not heated above 300° C. at which temperature anhydride formation begins, and (b) the gases leaving the system are still considerably below the point of saturation with water vapor.—*Note in J. Soc. Chem. Ind. on an article by P. Pipereaut and Helbronner in Monit Scient.*

Southern California Edison Company

Viscosity and Constitution of Lubricating Oils

THE average man troubles little about the exact constituents and the potencies of a complex medicine, a paint or an oil, because he feels that the information the expert might impart to him would probably not make him much the wiser. But he expects the expert to know and he is not pleased when the expert himself has to admit ignorance. For he may rightly suspect that he cannot rely on the quality of his product and that he may be made to pay excessively for the efficacy ascribed to certain ingredients, which may be absent or really of little value. All this applies strongly to lubricants. At present the oil supply is seriously restricted, oils are expected to do duty under extreme temperature conditions, high prices, possibly fancy prices, are charged, and the expert states viscosity, density, etc., but does not guarantee any performance. When the engineer looks for guidance in text books he finds contradictory information, and when Dr. A. E. Dunstan, F.I.C., and Dr. F. B. Thole brought the "Relation between Viscosity and Chemical Constitution of Oils" up for discussion at the meeting of the Institution of Petroleum Technologists on April 16, they introduced their paper by the remark that profound ignorance still prevailed as to the chemistry of the high-boiling components of petroleum, though the most important poperties of such oils, viscosity, "oiliness" and "gumming propensities" depended on the nature of these compounds. This ignorance is due to the difficulties of the problems much more than to neglect of research; the trouble is that oils are too oily, too ready to intermix and to share properties, too much opposed to differentiating.

The high-boiling fractions of petroleum are certainly very complex and far richer in unsaturated hydrocarbons of compositions from C_nH_{2n} down to C_nH_{2n-8} than in saturated paraffins C_nH_{2n+2}. Mabery isolated a few of these compounds from crude American oils; Engler converted amylene and hexylene by heat and pressure into products rich in naphthenes and resembling Baku cylinder oil; Dabatier and Senderens obtained products resembling lubricants by the catalytic action of nickel on acetylene. But in no case, Dr. Dunstan stated, had the chemical constitution of a component of lubricating oils been established. There were some saturated and more unsaturated hydrocarbons (possibly open-chain, more probably naphthenic or polynuclear, but not paraffinoid), and to small extent aromatic compounds and further compounds containing sulphur and oxygen. These latter resinous compounds had been isolated by Holde by treatment of the oil with alcohol and ether; they were probably responsible for the gumming which did not occur after the removal of the resins. Agitation with concentrated sulphuric acid removed a good proportion of unsaturated compounds; in the further presence of formaldehyde or of methylal [$CH_2.(OCH_3)_2$] the so-called formolitse of Nastyukov and of Heer feel out. But the statement that the remaining oil should be richer in hydrogen was not confirmed by Dr. Dunstan, nor by Mabery and Mathews, and Nastyukov questioned the statement by Marcusson that the remaining oil contained the essential lubricating constituents. There was thus much divergence of opinion—the names mentioned are those of chief investigators—but the suggestion of Schneider and Just, that lubricating oils were colloids opened up important considerations.

In their own researches Drs. Dunstan and Thole first determined the viscosity of the oils and its temperature coefficient by means of the Ostwald apparatus [which consists of a bulb joined by a capillary tube, the whole forming a U or an H] expressing their results in absolute units. The viscosity would depend upon the molecular structure and arrangement, and thus upon the molecular weights, which might vary from 16 up to several hundred. Mineral lubricants being refined petroleum hydrocarbons, the three constitutive variables were unsaturation, conjugation and symmetry. A lubricant should have low viscosity, high lubricating power, and great stability. The viscosity should be low, to prevent needless absorption of energy and heat generation by internal friction. On the other hand, the oil should possess what was designated "body" or oiliness, a property probably connected with viscosity and with capillarity. Very little was known about the surface tension of lubricating oils. Oil having a lower surface tension than metal would spread over it, as would water; but the water film—of greater surface tension than oil, but of very low viscosity—would be squeezed out. Oil formed a thicker film, the important property of which might be adhesion or film strength, the resistance which the oil opposed to rupture. That property did not always go together with viscosity; for solutions of sucrose and of glycerol possessed high viscosity, but were useless as lubricants. Unfortunately there existed no mechanical testing machine for determining the lubricating power. Dr. Dunstan mentioned that he is now experimenting with a very simple device, capillary glass tube, by the aid of which he can determine the viscosity and, from the weight of the falling drops, also the surface tension. The apparent connection between oiliness and high molecular weight, he pointed out, would support the suggestion that lubricants were colloids, or rather iso-colloids, *i. e.*, polyphase systems in which the disperse component (the colloidal particles) was of the same nature as the dispersion medium (the liquid in which the particles are suspended). In a sense water was one of these colloids, inasmuch as water was supposed to contain, not only molecules H_2O, but also molecules $(H_2O)n$, where n might be 2 or 3 (di- and tryhydrol). If lubricating oils were iso-colloids one could understand the hysteresis effects observed in heavy oils, and the fact that at higher temperatures all the high viscosities of the oils dropped rapidly, finally in all cases to very low values. It is interesting in this connection that Dr. Dunstan has actually been able to observe the colloidal particles with the aid of a parabolic substage condenser of his and of the ultramicroscope. He places a drop of liquid in a little hollow (made in a glass plate) underneath the condenser, and illuminates the liquid from below through the glass. When the liquid is water the field remained dark; in the case of oil, images of the particles are produced by diffraction, and he estimates that the oil particles would have a maximum diameter of 0.03 mm.

As regards stability and durability of the oils, a high percentage of inert paraffinoid hydrocarbons would be preferable to the presence of unsaturated compounds which were more likely to react chemically and to change; but the former had little lubricating value, though Dr. Dunstan did not mean to imply by that statement that they are of no use in lubricants. Lubricants are mixtures which are to possess a variety of properties which can apparently be secured only by using mixtures. When, however, the unsaturated compounds of an oil were removed by treatment with sulphuric acid or by some other treatment, Dr. Dunstan found the remaining oil had a smaller specific gravity and a smaller viscosity than the oirginal oil, throughout the whole temperature range, though the viscosities approached one another at high temperatures. Dr. Dunstan prefers—with other scientists—to plot the logarithms of the viscosities (rather than the viscosities themselves) against temperature, because the curves then practically become straight lines over a wide range of temperature; these logarithmic curves of the original and the treated oils tended to intersect. Together with Dr. Thole he also conducted elementary analyses, difficult to perform, of the original and the treated oils, in order to determine the ratio of carbon to hydrogen, and he further determined the molecular weights by observing the freezing-point depression of pure naphthalene. Though this latter method when applied to mixtures (as distinct from pure substances) can only yield average results, the figures clearly showed that the resulting hydrocarbon (deprived of most of its unsaturated constituents) had a higher molecular weight. From these various tests and further the iodine and bromine values they finally conclude that a lubricating oil should contain a certain proportion of unsaturated compounds, and that this proportion should be as large as was compatible with moderate liability to reactivity in general, oxidation, polymerization, gumming; dilution with saturated hydrocarbons would not assist lubrication, but would interfere with the display of chemical activity. The physical condition of the lubricant should be colloidal; that again would point to the importance of the unsaturated compounds, since unsaturation and complex assocaition generally go together. It is very striking that no lubricating oils have, so far, been synthetized, though Kramer and Spilke and Engler (already mentioned) have made some promising researches.

One practical consequence of this investigation was pointed out during the discussion by Mr. Anfilogoff. Too much attention is being paid to the pale color of lubricants; the colorless condition is secured by the plentiful use of strong sulphuric acid which removes the unsaturated compounds, some of which are certainly essential. What really constitutes oiliness and on what lubricating power depends, remains obscure. Mr. Butterfield quoted a remark to this effect which Mr. C. V. Boys made in his presidential address to the Physical Society last February. Vapor tension, boiling point and surface tension are undoubtedly concerned; certain official tests rightly insist that the lubricant should have been kept at low temperature for some time before being tested. Why the more slippery animal and vegetable oils are on the whole superior as lubricants to mineral oils is not understood. Dr. Dunstan and Dr. Thole have so far chiefly studied mineral oils; but they did observe that the excellent lubricant sperm oil, which chemically stands apart from most lubricants, has a low temperature coefficient of viscosity. Lubricants are used at high pressures and temperatures, but are not tested under these conditions, for want of suitable apparatus. Thus, further mechanical and chemical researches are needed; but colloidal investigation should strongly be urged, too. It would no doubt benefit the problems of lubricants as it has been of vast service in the rubber, silk, textile and pottery industries.—*Engineering.*

Carbide as a Propellant

A TRIAL trip was recently made in an 8 horse-power motor-boat fitted with an acetylene gas producer. The expenditure of energy, measured by a 3 horse-power two cylinder motor, is 0.7 kg. of carbide per horse-power an hour. The number of revolutions is the same as when pure petrol is used. The apparatus can be used in motors up to 25 to 30 horse-power, and in motor-cars successful results have already been obtained.—*Verdens Gang.*

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